

**2.3.1.4 Fluid Discharges from Tank Farm Operations.** During the operational history of the A-AX and C Tank Farms, fluids were discharged into the vadose zone, both deliberately and inadvertently. A list of intentional discharge sites and unplanned releases with descriptive information is provided in Appendix A from Williams (2001). Liquid discharge events are summarized by tank farm in the following paragraphs.

**2.3.1.5 Intentional Releases.** Unlike some tank farms at the Hanford Site, WMA C is not near many liquid waste disposal sites. At C farm the only intentional discharge facility was the 216-C-8 french drain, located about 75 ft (23 m) southeast of the 241-C Tank Farm. The drain is a 6-foot (1.8 m) diameter, 8-foot (2.4-m) long, gravel-filled concrete pipe placed vertically in the ground. It was used between June 1962 and June 1965 and received an unknown amount of ion-exchange regeneration waste from the 271-CR control house (DOE 1993b). The waste volume was not large compared to crib discharges. There is no indication that intentional releases had any significant impact on vadose zone contamination.

A greater number of intentional liquid discharge facilities were used around A and AX Tank Farm but the high discharge facilities were not adjacent to the tank farms. The high discharge facilities received condensate and cooling waters from PUREX operations and condensate generated in numerous tanks in A and AX Tank Farm because of high heat conditions. High discharge cribs that received waste from the tank ventilation systems included 216-A-8 and 216-A-24. Crib 216-A-8 lies about 500 ft (150 m) east of AX Tank Farm and received  $1.15 \times 10^9$  L between 1955 and 1995. Crib 216-A-24 lies about 600 ft (180 m) northeast of AX Tank Farm and received about  $8.2 \times 10^8$  L 1958 and 1966. Crib 216-A-9 about 300 ft (100 m) west of A Tank Farm operated intermittently with the largest discharges occurring from 1956 to 1958 when PUREX acid fractionator condensate and cooling water were released into the crib. A total of  $9.8 \times 10^8$  L was discharged to this crib. Contaminants in these large discharge cribs did break through to groundwater. However, it is not likely that they impacted the vadose zone beneath the WMAs because they are located too far from the WMAs.

Numerous cribs and retention basins around and French drains in A and AX Tank Farm received PUREX cold startup waste, stack drainage and cooling water mostly from the mid 1950s through the 1970s. These facilities generally received between  $10^4$  and  $10^6$  L. As with the larger discharge facilities, there is no indication that discharge to these facilities had a significant impact on contaminant migration.

**2.3.1.6 Unintentional Releases.** Several unplanned release (UPR) incidents have been reported within and around C, A and AX Tank Farms over the course of tank farm operations history. These are shown in Appendix A (Table A-1 of Williams 2001) and briefly described in Appendix B, Section B.5. Those releases identified as tank leaks are discussed in more detail in Section 3.3. The following paragraphs discuss UPRs other than those identified as tank leaks.

Around C farm, the largest UPRs were transfer line leaks near diversion boxes 241-CR-151, 241-C-152 and 241-C-151 (UPR-200-E-86). All involved the transfer of PUREX waste around 1970. Estimated losses were 136,000 L of CWP (UPR-200-E-81), 10,000 L of PSN (UPR-200-E-82) and an unknown volume of PSN waste (UPR-200-E-86) that was reported to contain 25,000 Ci of cesium-137. The remaining 9 UPRs were primarily small surface spills and airborne contamination. With the exception of UPR-200-E-16 (an estimated 190 L leak from an

over ground transfer line between tanks C-105 and C-108) these events occurred outside the C Tank Farm.

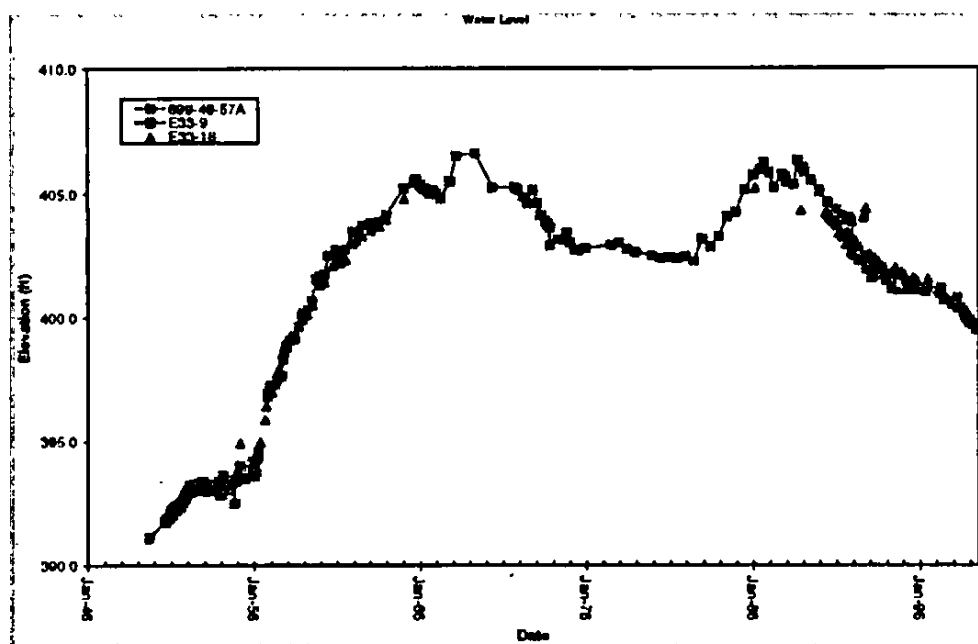
Around A Tank Farm two small UPRs occurred, a brief pump pit leak at tank A-106 (UPR-200-E-48) and leakage around transfer pipe near valve pit 241-A-08 east of the tank farm identified from contaminated soil (UPR-200-E-145). Around AX Tank Farm two small surface contamination events (UPR-200-E-42 and UPR-200-E-119) and an airborne event (UPR-200-E-155) occurred. None of these events apparently caused significant vadose zone contamination.

### **2.3.2 Subsurface Discharge**

**2.3.2.1 Vadose Zone Moisture Distribution.** Fluids leaked from cribs and trenches could have migrated laterally into the vadose zone beneath the C and A-AX WMAs. However, no evidence exists to indicate that such lateral migration has occurred. Given that more than 20 years have passed since the discharges occurred and that the soils are highly permeable, any fluids of sufficient quantity from these sources have likely migrated from the cribs and trenches downward toward the water table. Vertical migration due to infiltration driven recharge from natural sources can be estimated by assuming an average recharge rate in the range of 5 to 10 cm/yr. If an average recharge rate of 7 cm/yr is assumed along with an average water content of about 10 percent by volume, the pore water velocity will be 10 times the recharge rate or 0.7 m per year. Assuming no fast pathways (vertical channels, etc.) the expected limit of fluid migration is approximately 14 m below the original depth of the leak as documented in *A Comprehensive Analysis of Contaminant Transport in the Vadose Zone Beneath Tank SX-109* (Ward et al. 1997). It should be noted that the cribs and trenches received millions of gallons of discharge water. These large volumes would likely extend to groundwater, particularly in and near the cribs. During the past 20 years, discharge liquids would have been flushed about an additional 14 m downward to the water table by precipitation, not that the actual discharge liquids are only 14 m below the crib bottom.

**2.3.2.2 Water Table Fluctuations and Artificial Recharge.** The water table and general groundwater flow direction have changed significantly in the 200 East Area since large intentional discharges from processing plants and tank farm operations began in the early 1950s. In the 200 East Area, intentional discharges to B Pond located about 1.6 km (1 mi) east of the B-BX-BY WMA and 0.4 km (0.25 mi) east of A-AX and C WMAs have been particularly influential. Historical well data shown in Figure 2-9 around the B-BX-BY WMA show the water table rise that began in the early 1950s and continued until the mid 1980s. A similar profile would have occurred at the C and A-AX WMAs. In addition, the pre-Hanford operations flow directions (generally west to east) became more southerly and westerly as the B pond groundwater mound developed. When the B Pond discharges to B Pond and other liquid discharge sites were significantly reduced beginning in the 1980s, water table elevations began to drop toward pre-Hanford levels (see Table 2-10 showing relatively current levels) and general flow directions began to return to the more easterly pre-Hanford condition. In 5 to 8 years, some wells will contain little water as the water table is expected to decline in most parts of the 200 East Area an additional 4 to 5 m (13 to 16.4 ft). Given the transient hydrological conditions in this region, long-term water levels are difficult to predict.

Figure 2-9. Historical Water Levels Near the B-BX-BY WMA.



## 2.4 HYDROLOGIC PROPERTIES

### 2.4.1 Vadose Zone Properties

A summary of vadose zone hydrologic properties collected at the Hanford Site is provided in *Variability and Scaling of Hydraulic Properties for 200 Area Soils, Hanford Site* (Khaleel and Freeman 1995). A subset of this database is included in Appendix C, Table C-1. The most pertinent data were collected on Hanford formation soils underlying the BY cribs during the remedial investigation of the 200-BP-1 operable unit. Because of the distance between C, A and AX Tank Farms and most of the sampling sites, these data cannot be considered to be waste site-specific. However, there are sufficient similarities in their depositional environment to make the data potentially comparable. The database includes the location of the sample, the depth at which the sample was collected, particle size distribution, moisture retention curve data, and saturated hydraulic conductivity values. Generally, the soils are variable mixtures of sands and gravels. Well-defined horizontal strata with distinctly different hydraulic properties favoring lateral movement in the vadose zone (e.g., silty sands) are probably present locally, but are not widespread.

The water table is approximately 250 ft (75 m) below the surface at the C WMA and approximately 290 ft (83.4 m) below the surface at the A-AX WMA. Consequently, much of the migration pathway from the source to the groundwater monitoring well will be in the unsaturated zone. Liquid migration through this zone is influenced by soil grain size distribution heterogeneities and directional (lateral versus vertical) anisotropy in the soil permeability. The

bulk of the sediments are high-energy flood deposits with extreme variability in grain size over vertical and horizontal intervals on the order of tens of feet. Hydraulic conductivity values would be expected to change on at least the same scale if not less.

In the 200 East Area, unsaturated sediments are primarily gravelly coarse-grained sands and sandy gravels with a few thin intermittent silt-rich units, there are no low-permeability horizons that would cause appreciable lateral spreading of infiltrating liquid under the A-AX WMA. The detailed stratigraphic description provided in Section 2.2 shows a vertical column of predominantly coarse sands in the vadose zone. The slight doming effect seen at the top of the Ringold formation at the A-AX WMA appears to be carried through to the contact between the Hanford upper gravel and sand sequences. These subtle structures and changes in lithologies may control local flow directions for liquid migrating through the vadose zone. However, it is not possible to model or predict specific pathways. The C WMA does not appear to have such a feature that potentially could control flow in the vadose zone.

Studies of aqueous flow in sandboxes suggest that one common pattern of flow through unsaturated sediments is in relatively narrow, vertical fingers with some lateral spreading occurring at silty horizons. Once saturation of these horizons is reached, vertical flow commences again. Furthermore, once these vertical pathways are established with an initial infiltration event, liquids from later infiltration events will flow along these established channels (Stephens 1997). The cross-sections portray that the bulk of the sediments in the vadose zone should promote vertical transport of migrating fluids. The fine-grained sequence at the top of the Ringold may cause some lateral spreading at depth.

Evidence in support of this type of flow behavior in the 200 East Area comes from direct observation of infiltration tests performed at the 200E/105A Mock Tank Site (Narbutovskih et al. 1996). Electrical resistivity tomography was used to track leaking saline water from the surface to a depth of about 70 ft (21.3 m). Results indicate that this type of fingering does occur. Furthermore, analysis of the infiltration rate, the time to reach depth and the total volume of water leaked indicates that a point source leak of 0.13 gallons per minute (0.49 L/min) might reach groundwater in a few months (Hartman and Dresel 1997).

The sandbox studies and the infiltration tests suggest that relatively moderate volumes of liquid (~10,000 gals [37,854 L]) can travel rapidly through the vadose zone in the 200 East Area. Extrapolation of these data to the entire depth of the vadose zone suggests that a several thousand-gallon discharge could reach the aquifer in some time period less than a year. However, no field data demonstrate this occurrence and modeling studies have yet to predict such rapid migration through the vadose zone.

In several areas of the Hanford Site, clastic dikes exist in the subsurface. Clastic dikes may provide limited vertical pathways for rapid liquid migration from the surface to the groundwater. The observed clastic dike characteristics (Fecht et al 1999) suggest that these features do not extend as far as the vadose zone thickness and are oriented in a three-dimensional fashion, being neither strictly vertical nor horizontal. If clastic dikes do exist under the farms, a pathway might exist that allows local rapid vertical movement of fluids in the vadose zone but large-scale control of fluid migration is unlikely.

Other migration pathways that would allow local rapid vertical flow are the outer annulus of poorly sealed or unsealed drywells within the farm boundaries. Water may enter from the surface to flow downward along the outside of the well casing if the sealant material does not properly adjoin the casing. Contamination in the vadose zone may also enter an annular space via discontinuities in the seal column, such as a “bridge” caused by careless emplacement of sealant materials, and then flow downward between the flawed seal and well casing. These wells are used for vadose zone monitoring with gamma ray logging tools and extend to depths of approximately 100 to 150 ft (30.4 to 45.7 m) below the surface.

## 2.4.2 Aquifer Properties

This section provides information on the current nature of the unconfined aquifer in the immediate region of the C and A-AX WMAs. Aquifer properties were determined from lithographic and stratigraphic interpretations, current water elevations, and direct test methods. Aquifer properties described include: aquifer thickness, hydraulic gradients, hydraulic conductivity, and porosity. The estimated values for flow direction and velocity are also discussed in this section based substantially on the measurement and interpretation of the aquifer properties. Additional detailed data can be found in *Hanford Site Groundwater Monitoring for Fiscal Year 2000* and *Hanford Site Groundwater Monitoring for Fiscal Year 2001* (Hartman et al., 2001 and 2002).

Based on local hydrographs and colloidal borescope measurements, it has been determined that the groundwater flow direction is generally to the southwest to south-southwest at C WMA and to the southeast at A-AX WMA. These flow direction directions are consistent with the regional water-table map (see Plate 1 Hartman et al., 2002). Using measurements from pumping tests results, hydraulic gradients, porosity estimates, and the colloidal borescope measurements the groundwater flow rate ranges between 2.4 and 4.8 ft (0.7 and 1.4 m) per day for C WMA and between 5.6 and 10.8 ft (1.7 to 3.3 m) per day for the A-AX WMA (Hartman et al. 2002 and Hartman et al. 2000).

**2.4.2.1 Aquifer Thickness.** Currently, the water table beneath the C WMA lies 400 ft (122 m) above sea level with about 255 ft (77 m) of vadose zone above. The aquifer thickness, based on the top of basalt at 355 ft (108 m), is approximately 44 ft (13.4 m). The aquifer materials consist dominantly of sandy gravel or silty sandy gravel. At the A-AX WMA the water table lies in basal gravels currently interpreted as Ringold Formation Unit A. As explained in Section 2.2, there is some ambiguity as to the location of the Hanford/Ringold contact in this area with respect to the water table. The aquifer thickness, based on data from well 299-E25-2, which extends to basalt, is approximately 89 ft (27.1 m). The lithology within the aquifer is dominantly a sandy gravel ranging from cobble to boulder-sized clasts.

**2.4.2.2 Hydraulic Gradients.** The water table is extremely flat across the 200 East Area (Figure 2-10), and in areas with flat water tables the choice of surveys may actually affect the relative position of the water elevation in a well with respect to other network wells. Because water elevations are the most common data set used at the DOE Hanford Site to determine flow

direction, a switch in the relative water elevations of wells used to determine direction could affect the interpretation of the flow direction.

The groundwater project recently switched the datum to which water levels are referenced in *Hanford Site Groundwater Monitoring for Fiscal Years 1998, 1999, 2000, and 2001* (Hartman 1999; Hartman et al., 2000, 2001, 2002). In the past, water levels were referenced to the NGVD29 datum. The NGVD29 datum was chosen originally because the bulk of the wells used on site could be referenced not only to this datum but also to a specific survey called NGVD29-2. For areas the size of a WMA, there is no effect from switching to the NAVD88 datum. However with the datum change, there was also a switch in surveys. Many wells are now referenced to one of two surveys, with elevations referenced to NAVD88, both more recent surveys than NGVD29-2.

Figure 2-11 shows hydrographs for four of the five RCRA network wells that are currently used to monitor the water table at the C WMA. The water level data from well 299-E27-15 had been historically inconsistent with data from the other wells in the WMA C network and with the regional water table data (Hartman 1999). Corrections to water elevations based on the recent results of gyroscope surveys at the C WMA including this well provide a more consistent and thus interpretable water table surface (Hartman et al., 2002). Water table elevations across the C WMA vary from 402.3 to 402.8 ft (122.62 to 122.77 m). The local gradient between well 299-E27-7 and 299-E27-13 is 0.00021 based on June 2000 water levels.

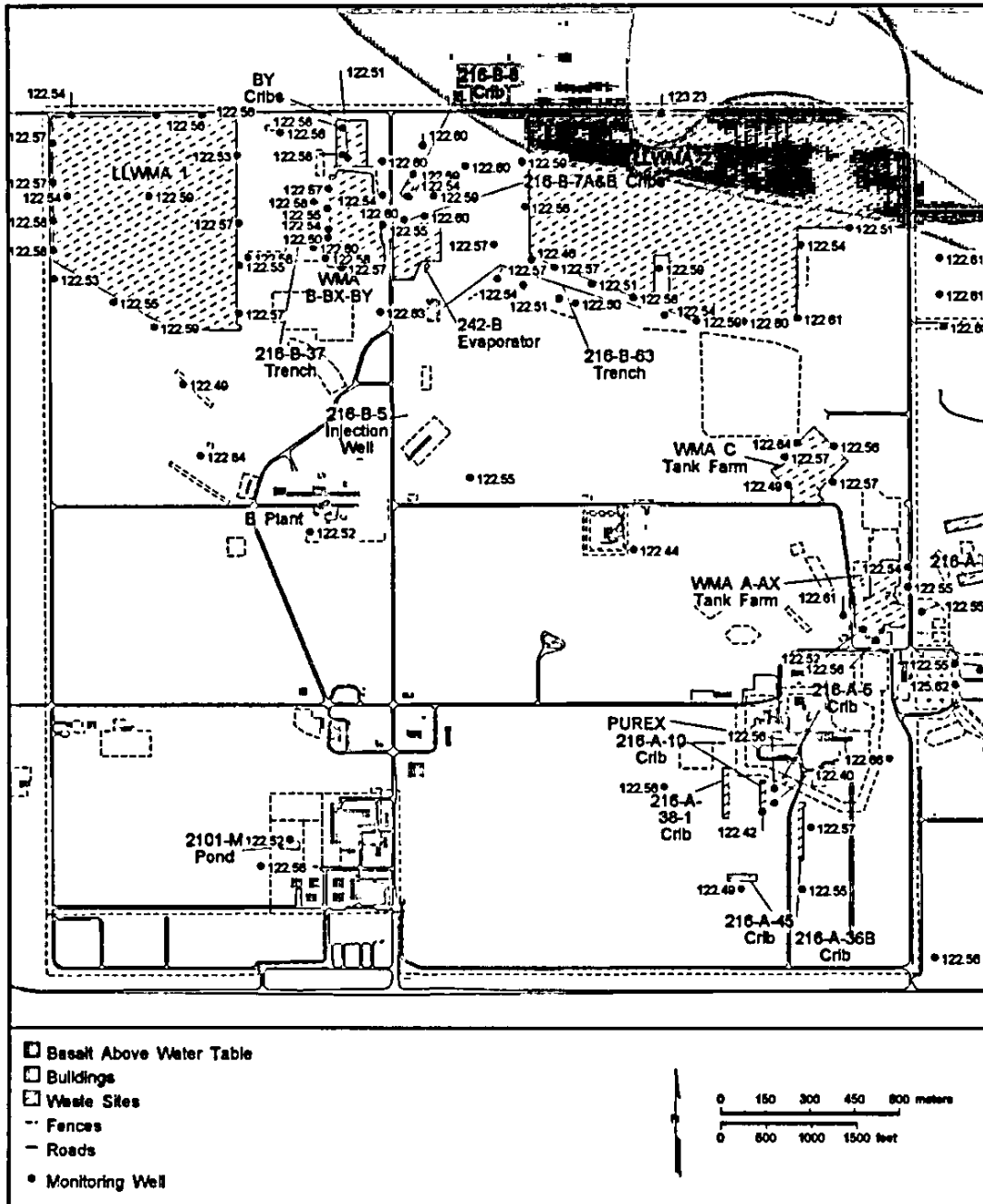
Hydrographs of the two wells at the A-AX WMA gives a consistent picture of relative water elevations over time (Figure 2-12). The flow direction appears to be southeast. Based on these hydrographs, well 299-E24-20 is the upgradient well, while the other four are down gradient. Using NAVD88-1, water elevations across A-AX WMA vary from 402.9 to 403.1 ft (122.80 to 122.86 m) or 2.4 in. (6.1 cm). The local gradient between well 299-E25-41 and 299-E24-20 is 0.000078 based on March 1999 water levels.

Another well, 299 E24-19, was eliminated from the analysis because results from this well form a slight trough between E24-20 and E25-46. The water elevations in this well are low regardless of which survey is used, which has confused interpretation of the flow direction in the past. Based on recent findings with vertical borehole deviations, this well may be slightly out of plumb, explaining the abnormal trough. Consequently this well was eliminated from the network for flow direction determinations until gyroscope corrections are available.

**2.4.2.3 Hydraulic Conductivity.** Although there is some consolidation of the sediment within the unconfined aquifer at both WMAs, there is little evidence of significant compaction or cementing. Consequently, permeability is high within the aquifer. Currently, there is a discrepancy in reported hydraulic conductivity values in the area. Values are estimated between 24 and 110 ft (7.3 and 33 m) per day based on slug injection/withdrawal tests. Higher values of 6,500 ft (1981 m) per day are reported from pumping tests in the area (Newcomer et al 1990; Connelly et al 1992). Connelly (1992) reported hydraulic conductivity values for the C WMA between 3,500 and 6,800 ft (1,067 and 2072 m) per day and between 6,200 and 6,500 ft (1,890 and 1,982 m) per day at the A-AX WMA. Trent (1992) reported conductivities that range from 8,264 to 6,500 ft (2,519 to 1,890 m) per day for wells near the A-AX WMA. Finally, Hartman

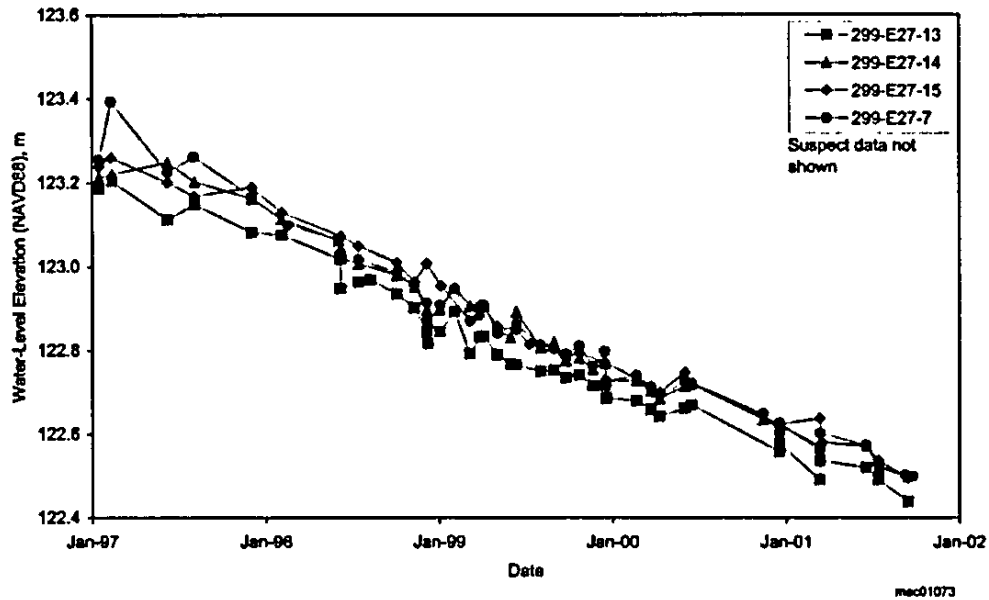
(1999) reported hydraulic conductivities that range from 33,000 to 9,843 ft (10,000 to 3,000 m) per day for Hanford sediments.

Figure 2-10. Water Level Elevations in the 200 East Area in March 2002.

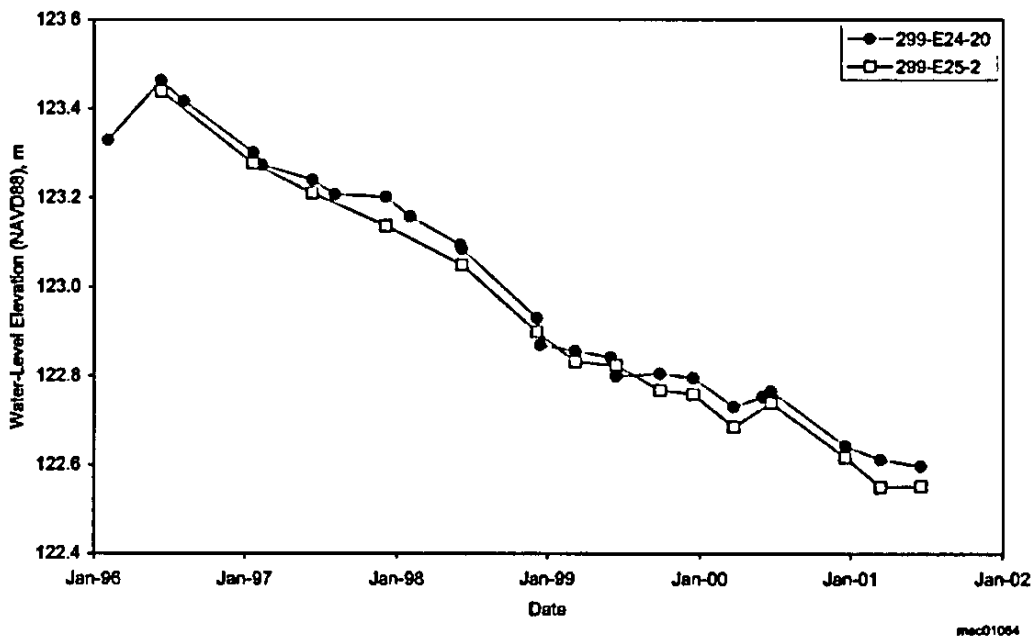


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**Figure 2-11. Hydrographs for Wells in the WMA C Monitoring Network. All data referenced to the NAVD88 datum. Spurious data have been removed.**



**Figure 2-12. Hydrographs for Two Wells in the WMA A-AX Monitoring Network. All data referenced to the NAVD88 datum. Spurious data have been removed.**





Two factors likely contribute to the measurement discrepancies. First, since the early 1990s the water table has dropped from the more permeable Hanford formation into the less permeable undifferentiated Plio-Pleistocene/Ringold Unit. The higher conductivity measurements were taken when the water table was elevated and reflected the influence of the Hanford formation on the overall permeability of the unconfined aquifer. Second, slug tests involve a more limited areal extent than pumping tests and tend to provide lower measurements. Slug tests apply a limited stress to the aquifer and are valid over a limited range of conductivities (Thorne and Newcomer 1992). Because the water table is expected to remain in the less permeable stratigraphic unit, an estimated hydraulic conductivity range of 15 to 150 ft (5 to 50 m) per day is estimated.

**2.4.2.4 Porosity.** Porosity is generally estimated to be about 30% for unconsolidated, coarse-grained sediments at the DOE Hanford Site (Hartman 1999). Because it has not been possible to collect intact core from the aquifer during past drilling, direct methods of determining porosity have not been used. The lack of direct measurements combined with the cobble to boulder grain size of the aquifer suggests 30% may be approximately correct or slightly high value for porosity. Where boulders and cobbles are present and mixed with sand and gravels in the interstices of the larger cobbles a value closer to 20% may be more appropriate for effective porosity (Eckis 1934, Evenson et al., 1962).

**2.4.2.5 Flow Direction.** The hydraulic gradient is relatively gentle across the 200 East Area. With about 6-in. (15 cm) across the C WMA and 2.4 in. (6 cm) of change across the A-AX WMA, the exclusive use of discrete water elevations to determine flow direction is not recommended. Although this low gradient is caused, in part, by the dissipating groundwater mound under B-Pond, it is primarily due to the high aquifer transmissivity in the 200 East Area with respect to upgradient regions farther west where transmissivity is considerably less. Before formation of the groundwater mound beneath B-Pond, the groundwater flowed regionally to the southeast towards the 300 Area. Recent interpretations of current flow direction show a southwesterly flow from the C WMA and turning more southeasterly at the A-AX WMA where the aquifer is more than twice as thick and the regional southeasterly flow pattern becomes dominant (Williams et al., 2000, Hartman et al., 2002). These patterns are consistent with regional flow directions.

Although the predominant flow directions at these two WMAs are consistent with the regional flow directions and plume trends, as evidenced over miles, they can be misleading when determining the local flow anomalies across these small sites that are 500 ft wide (152.4 m). Some suggestion of the complexity of flow patterns in the 200 East Area is shown by direct measurements shown in Figure 2-13. The large variation in flow directions may be somewhat exaggerated because the effects of well design and rapid changes in barometric pressure, which are not accounted for in Figure 2-13. It is known that wells south of PUREX can have large changes in flow direction in a single day because of their barometric efficiency.

Until this year, the flow direction at these two WMAs had been determined exclusively from gradient calculations based on local water elevations. Unfortunately, across the 200 East Area, the differences in water elevation between wells are small, on the order of a few inches. The combined errors from water level measurements, survey elevations and borehole deviations from

vertical are enough to cause uncertainties in local flow direction anywhere in the 200 East Area. As reported in Hartman et al. (2000), water level data alone are insufficient to determine flow direction in this area. Direct flow measurements were made in several wells at these tank farms to help determine flow direction and thereby minimize the uncertainty in flow direction. In addition, colloidal borescope measurements have been added at site-specific wells to improve the database for interpreting local flow directions.

At the C WMA where barometric effects are usually minor and suspect data were intentionally avoided, the flow direction determined in well 299-E27-13 had a southwest flow direction, which was measured for more than two hours, and had no significant vertical component (Figure 2-13). The similar southwest flow direction determined in well 299-E27-14 had similar quality, but was recorded for only 36 minutes. Therefore, the value, which is shown in gray, is accepted as valid with caution. The flow directions of the other two arrows shown in gray for wells 299-E27-7, 299-E27-12 are very questionable because of their large vertical components.

Recent direct flow measurements with the colloidal borescope in wells 299-E27-14 (southeast of C Tank Farm), 299-E27-13 (southwest of C Tank Farm), and 299-E27-7 (northeast of C Tank Farm) indicate an average southwesterly flow direction of approximately 214 degrees from true north. Actual measurements in these three wells range from 200 to 235 degrees from true north. Only well 299-E27-12, which is located west of the C Tank Farm, indicates an easterly flow direction as shown in Figure 2-14. However, the two interpretable measured values in this well are suspect because they represent vertical flow, which may be related to their close proximity (i.e., less than 0.45 m) to the water table surface in the well.

According to water table elevations based on surveys referenced to NAVD88 and colloidal borescope data, the direction of flow at the C WMA appears to be predominantly southwest. The current monitoring network was designed for a flow direction to the west with two upgradient wells, 299-E27-7 and 299-E27-14, and three downgradient wells, 299-E27-12, 299-E27-13, and 299-E27-15. As seen on Figure 2-14, only well 299-E27-13 is downgradient if the flow direction is southwest or south-southwest while well 299-E27-12 and 299-E27-14 are cross gradient, providing little if any coverage of the WMA.

At the A-AX WMA where barometric effects can have a more significant impact on borescope results, periods of significant barometric changes were avoided as much as possible when selecting flow direction data. Four of the five wells surveyed with the colloidal borescope near this WMA suggest an eastward to southeastward flow direction (Figure 2-15). The fifth well is the upgradient well 299-E24-20 that shows a westerly flow direction, but it tends to show higher water-table elevations than those wells southeast of the site. The cause of this seemingly anomalous flow direction is unknown, but may be influenced by the presence of the Plio-Pleistocene silt/Ringold formation mud facies near the water table surface or possibly some barometric effect. A sixth well, 299-E24-19 is deviated significantly from vertical, and therefore, the colloidal borescope could not be used in this well.

According to water elevations based on surveys referenced to NAVD88, the direction of flow is southeasterly. The current network was designed for a southwesterly flow direction with two upgradient wells (then 299-E25-40 and 299-E25-41) and only 3 downgradient wells, 299-E24-19, 299-E24-20 and 299-E25-46. However, recent measurements with the colloidal

borescope in wells 299-E25-46, 299-E25-42 (both southeast of A Tank Farm) and 299-E25-41 (southeast of AX Tank Farm) indicate a southeasterly flow direction of approximately 125 degrees from true north (Figure 2-15). Data from well 299-E25-40, which is located northeast of the A-X Tank Farm, indicated easterly flow. The data from this well indicated primarily vertical flow, thus the flow in the well may be deviated with respect to the surrounding aquifer due to local borehole conditions. Results from well 299-E24-20 display a southwest direction, which, although southerly, does not agree as well with either the water level data or the other borescope data. The results from this well may be due to borehole effects or other perturbations in flow due to local heterogeneities of permeability at this location. As shown in Figure 2-15 only well 299-E25-41 is down gradient. Well 299-E24-20 is marginally up gradient while wells 299-E25-19 and 299-E25-46 are marginally down gradient but only for the 241-A Tank Farm. This scenario results in a generally southeasterly flow direction across the site. This direction has been confirmed with the use of an alternative in situ method to determine flow direction. Recent direct measurements using the colloidal borescope in wells 299-E25-46 (southeast of A Tank Farm), 299-E25-41 (southeast of AX Tank Farm), and 299-E25-42 (southeast of A Tank Farm) indicate a southeasterly flow direction (Figure 2-15).

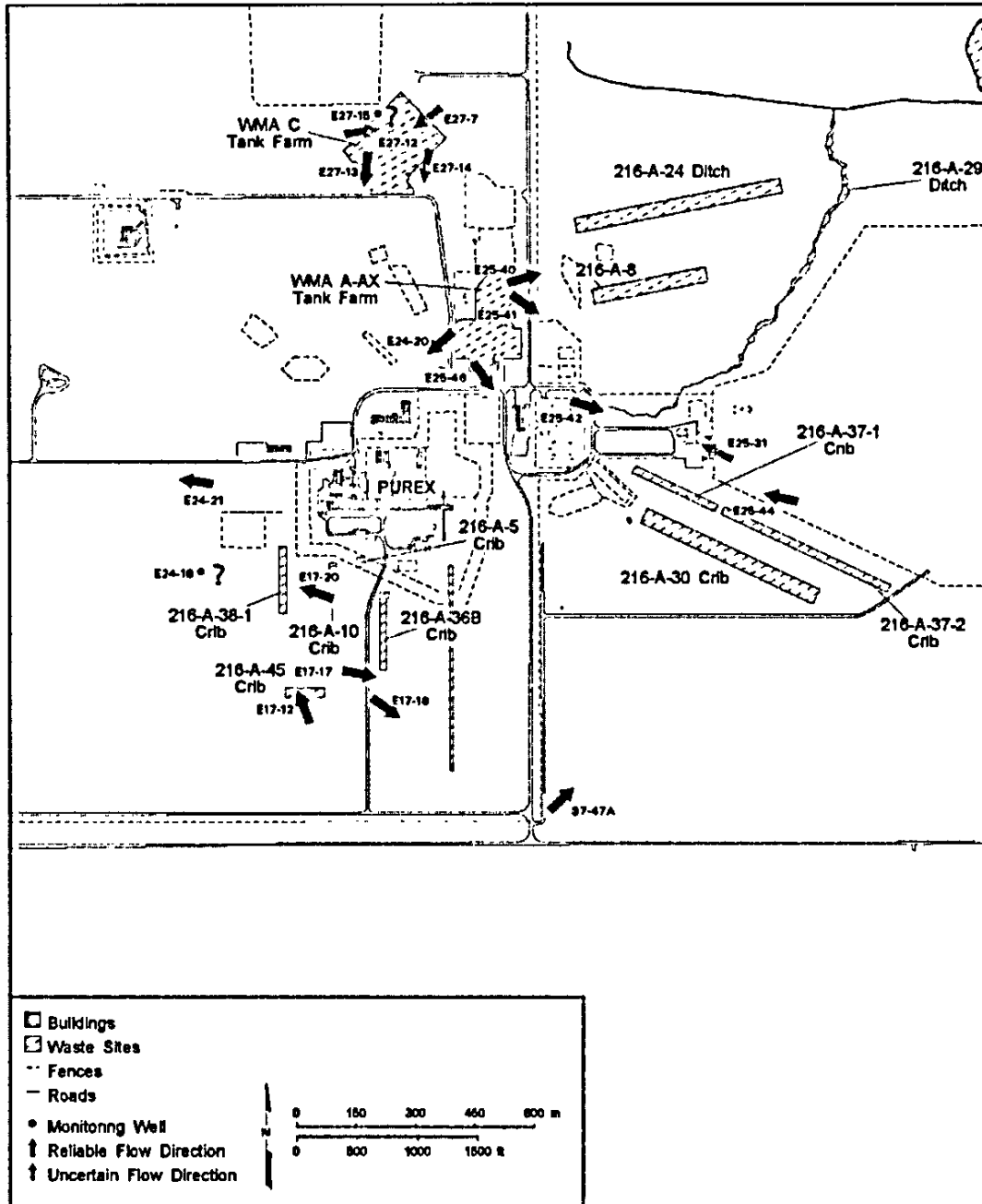
**2.4.2.6 Flow Velocity.** The rate of groundwater flow is calculated for a homogeneous, isotropic aquifer using the Darcy equation found in *Groundwater* (Freeze and Cherry 1979) incorporating the hydraulic conductivity, the gradient across the site and the effective porosity of the sediments in the aquifer. The current estimate is between 5.6 and 10.8 ft (1.7 to 3.3 m) per day for the A-AX WMA and 2.4 and 4.8 ft (0.7 and 1.4 m) per day for the C WMA (Hartman et al. 2002 and 2000).

At the C WMA values obtained from wells 299-E27-13 and 299-E27-14 using the colloidal borescope, after corrections for in well flow rates, indicate flow rates in the aquifer of 4 to 6.3 ft/day (1.2 to 1.9 m/day). These values for flow velocity, although higher than the current estimates of 2.4 to 4.8 ft (0.7 and 1.4 m) per day, are still within reasonable agreement with rates determined from the Darcy equation. However, in sharp contrast direct measurements of flow rates based on tracer tests and plume tracking suggest flow rates may be as high as 60 ft (18 m) per day in parts of the unconfined aquifer (Hartman 1999). The influence of the regional flow direction and velocity is demonstrated by the large tritium plume from PUREX waste disposed to the PUREX cribs, and the effective flow from the southeast corner of the 200 East to the east and southeast at rates from 14 to 18 ft (4.3 to 5.5 m) per day (Hartman 1999). However, these values are from an area where flow velocities are expected to be higher than in the C WMA because of slightly higher gradients and hydraulic conductivity southeast of the C WMA as evidenced by those at the A-AX WMA.

At A-AX WMA the flow rate may be in excess of the rate calculated from the ambiguous gradient data and the effective hydraulic conductivities and porosities. Direct measurements of flow rates based on tracer tests and plume tracking suggest flow rates in excess of 10 ft (3 m) per day (Hartman 1999). In-well flow rates, which are typically 1 to 4 times that of the rate in the natural sediments surrounding the well screen, were determined using the colloidal borescope. Values obtained from wells 299-E25-46 and 299-E25-41, corrected from in-well rates indicate aquifer flow rates of 1.5 to 7.5 ft/day (0.5 to 2.3 m/day), which span a similar, but slightly slower flow rate range than determined from the Darcy calculations.

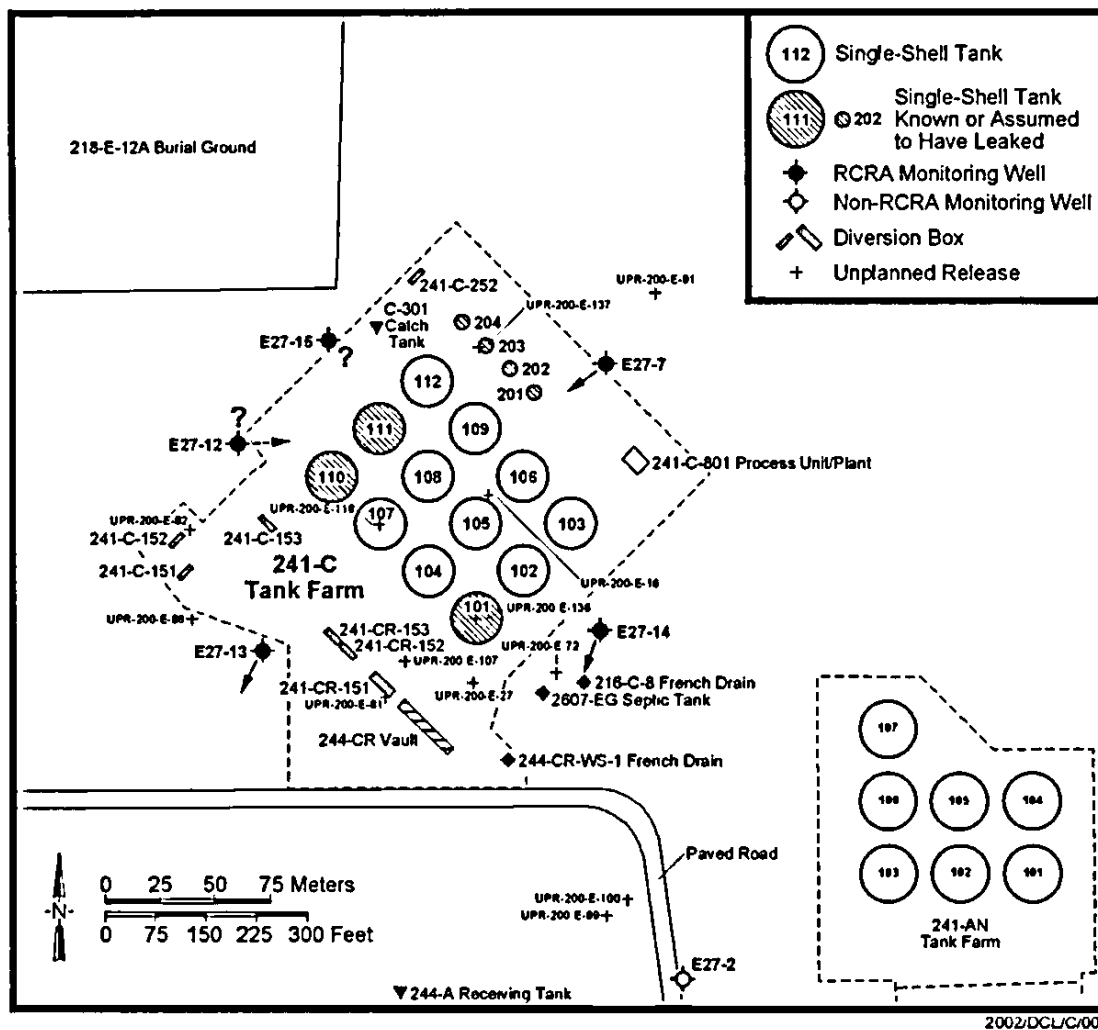
It is known that rapid changes in barometric may effect flow direction and velocities in wells, particularly if a semi-confined condition exists. During use of the colloidal borescope in the wells near A-AX and C WMA barometric changes were usually small, however, this was not always true for wells south and southeast of PUREX (see Figure 2-13). Also, semi-confined conditions were created by Plio-Pleistocene silt /Ringold formation mud facies present from the north end of A-AX WMA to south of PUREX (see Figure 2-5). Water table surface is usually just below this cap silt unit or partially confined by it. The upper surface of the silt layer dips to the SW and the lower surface dip has not been defined but is believed to be similar, but more irregular. A small thickness to none of unsaturated permeable sand and gravel is just below the bottom of this layer. As the water table changes with the barometric pressure, air rushes either into or out of the wells that penetrate this unit, which distorts the predominant flow direction periodically by as much as 180 degrees. This silt layer continues south and may connect to the lower Ringold mud as discussed in Section 2.2.

**Figure 2-13. Flow Direction Map of Wells in the Vicinity of Waste Management Areas A-AX and C Based on Colloidal Borescope Measurements.**



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**Figure 2-14. Flow Direction Map of Wells Around Waste Management Area C Based on Colloidal Borescope Measurements.**





## 2.5 GEOCHEMISTRY

This section covers geochemical factors and material properties of the vadose zone and unconfined aquifer underlying the C and A-AX WMAs. It addresses those factors that control contaminant mobility in the soil column. Radionuclide and hazardous-constituent mobility can be substantially different depending on the innate characteristics of the contaminant, the geochemistry of the natural soil-water system, and the changes in soil and water chemistry that occur from contact with tank fluid. In these soils, all factors are expected to be influential. Different contaminants present in the soils are variably mobile and, depending on interactions of tank fluids with the soil-water system, a given contaminant's mobility can be considerably different at different locations and times within the vadose zone and unconfined aquifer.

The geochemical characteristics and contaminant mobility are best considered in terms of behavior in relatively undisturbed soils versus soils that have interacted with tank waste fluids. In addition, tank fluid chemistry varies. Both types of soil conditions are expected in the vadose zone underlying the C and A-AX WMAs. For relatively undisturbed soils, a substantial Hanford Site-specific database is available that quantifies geochemical characteristics and contaminant behavior, particularly for radionuclides (e.g., Ames and Rai 1978; Serne and Wood 1990; Serne et al. 1993; Kaplan, Parker, and Kutynakov 1998, and Kaplan and Serne 1999). This database is not specific for the C and A-AX WMAs. Average soil properties are described in Section 2.2. Soil water in the vadose zone and groundwater in the unconfined aquifer have similar characteristics. They are moderately alkaline (pH about 8) and contain moderated concentrations of cations and anions. Dominant cations are calcium (about 50 mg/L), magnesium (about 14 mg/L), sodium (about 30 mg/L), and potassium (about 9 mg/L). Dominant anions are carbonate (about 70 mg/L) and sulfate (75 mg/L).

Within the C and A-AX WMAs, quantitative, site-specific radionuclide sorption/solubility data are not available. However, spectral gamma data from the drywell systems provide qualitative indications of the reactivity of detected tank waste constituents and some ability to compare radionuclide behavior known to occur in undisturbed Hanford Site soil environments. In contaminated regions containing several gamma-emitting radionuclides, spectral gamma data show that their spatial distributions relative to the expected source of leaks and to other radionuclides tend to be consistent. Given this database, the following observations are generally seen across the WMAs for the most commonly observed gamma-emitting radionuclides:

- Cesium-137 is concentrated in drywells near the potential sources of tank leaks. This suggests relatively rapid and complete sorption onto soil near the point of discharge. Vertical distribution in drywell 30-05-07 shows Cs-137 peaks coincident with the tank bottom and extending no more than 10 m deeper into the soil column. Several transfer line locations (e.g., between tanks C-104 and C-105, between tanks C-108 and C-109 and between tanks A-101 and A-102) are marked by sharp peak Cs-137 concentrations at transfer line depth. This behavior is consistent with measured  $K_d$  values in Hanford Site soil of more than 100 mL/g. For more detailed description of Cs mobility under tank farm conditions, see S/SX FIR.



- Cobalt-60 is highly mobile. When present in a drywell with Cs-137, it is routinely distributed below Cs-137 and the degree of separation between peaks can be tens of feet. The most obvious indication of Co-60 mobility occurs in the eastern portion of C Tank Farm where Co-60 occurs at and below 90 ft (27 m) bgs. In these instances, the chemistry of numerous tank fluids clearly plays an important role in providing complexing agents that cause  $^{60}\text{Co}$  to be highly mobile, with a  $K_d$  value near 0 mL/g.

This data suggests that tank fluid chemistry in these WMAs has had little observable effect on  $^{137}\text{Cs}$  mobility. In these tank farms,  $^{137}\text{Cs}$  continues to be highly reactive and immobile in the soil column and is a good indicator of leak source location. Assigning a  $K_d$  value of 100 mL/g or more is a reasonable estimate. Tank fluid chemistry does have a significant effect on  $^{60}\text{Co}$  and europium isotopes, reducing reactivity with the soil and enhancing mobility. Some small degree of sorption may occur, but assigning a  $K_d$  value of 0 mL/g is a reasonably conservative estimate. The particular fluid chemistry characteristics enhancing  $^{60}\text{Co}$  mobility are unclear and no distinctly different effects on gamma radionuclide behavior caused by variability in tank fluid chemistry are apparent. The location of  $^{60}\text{Co}$  also could show an approximate location of  $^{99}\text{Tc}$  in the vadose zone underlying the C, A and AX Tank Farms.

### **3.0 SUBSURFACE CONTAMINATION CHARACTERISTICS AND ASSOCIATED TANK WASTE INFORMATION**

Subsurface contamination has been generated by tank farm operations in the C and A-AX WMAs over the course of a long operating period from the mid-1940s until 1980. Tank farm operational histories have been described in Chapter 2 and Appendix A (narrative and tables from Williams [2001])). In this chapter, the available information about the nature and extent of subsurface contamination in specific locations within the WMAs is summarized. The primary data sources are gamma ray logging data, tank waste chemistry records and tank farm operations records. Because the gamma logging data are so important to this discussion, an overview of these data is provided in Section 3.1. A summary of characteristics for tank wastes that are the probable sources of subsurface contamination is provided in Section 3.2. In Section 3.3, data is described by specific area of contamination. Contamination discharged to the vadose zone from unplanned releases within the WMAs but located outside the tank farm is discussed in Appendix B. Available information on these releases is provided in Appendix B. A summary of tank leak determinations based on evaluations in this report is provided in Section 3.4. Finally, in Section 3.5, groundwater contamination around the C and A-AX WMAs is summarized. Although no C or A-AX WMA sources are known to have caused local groundwater contamination, groundwater characteristics are provided to complete the description of subsurface contaminant characteristics in and around the C or A-AX WMAs.

#### **3.1 GAMMA RAY LOGGING INFORMATION**

Two types of gamma ray logging data were collected in the C, A and AX Tank Farms. As part of a tank leak detection program (*A Scientific Basis for Establishing Dry Well-Monitoring Frequencies* [Isaacson and Gasper 1981]), gross gamma logging was conducted from the early 1960s through 1994. Recently, the gross gamma logging data from Tank Farms, C, A and AX were evaluated to assess potential movement of gamma-emitting radionuclides in the vadose zone (Randall and Price, 2001a, 2001b and Price 2001). More recently, spectral gamma logging data was collected for the C, A and AX Tank Farms (DOE-GJO 1998a, DOE-GJO 1999 and DOE-GJO 1997a, respectively).

##### **3.1.1 Spectral Gamma Logging Data**

The spectral gamma logging database is the most comprehensive database available that quantifies the nature and extent of subsurface contamination in the C and A-AX WMAs. Specific spectral gamma data that identify the most contaminated areas within in the C and A-AX WMAs are discussed in Section 3.3. In some cases, the spectral gamma data provide information that can be correlated with time-dependent waste transfer and storage records for specific tanks. This allows identification of specific waste types. The spectral gamma data also provide an independent means of evaluating the veracity of reported tank leaks. Drywell location maps in each tank farm and summary figures of the individual drywell spectral gamma logs are provided in Appendix E.

Some limitations are associated with the gamma logging methods.

- First, gamma logging interrogates only about 30 cm to 45 cm (12 to 18 in.) of the soil around the well.
- Second, uncertainties associated with distinguishing gamma contamination in the well or on the well casing from gamma activity originating in the soil may make data inaccurate.
- Finally, gamma activity monitored by these methods provides little information about the tank waste-related non-gamma-emitting radionuclides and chemicals.

These limitations must be considered in evaluating the referenced data reports.

The relationship between the leak status of single-shell tanks and spectral gamma logging data in nearby drywells is qualitative. However, both the depth of gamma activity and its intensity provide some ability to distinguish between failure of the tank and losses associated piping or tank overfills. Most easily distinguished are the cases where significant waste volumes engulf a section of the drywell. In these cases, Cs-137 activity is around  $1\text{E}+08$  pCi/g - depending on the waste type present; there are frequently other gamma emitters at much lower concentrations. This concentration of Cs-137 appears to represent the sorption capacity of the soil. If the high Cs-137 activity zones appear at or near the levels of the waste transfer lines or spare inlet ports then this is considered strong evidence for a piping leak or tank overfill event as being the origin of the contamination. High Cs-137 activity ( $>10,000$  pCi/g) beginning near the base of the tank provides strong evidence for a leak from the tank. Other situations are much more difficult to interpret.

Low levels of Cs-137 contamination are ubiquitous in drywells around most single-shell tanks. It appears that open boreholes provided a pathway for contamination to enter the well casing and in some cases, the unsealed boreholes provided a pathway for contamination to move downward. In addition, the compacted base on the original tank farm excavation provided a region for liquids to pond and move laterally. The Cs-sorption chemistry predicts that the Cs-137 is held in a highly concentrated plume with sharp activity drops at the edge. Thus, when low Cs-137 activity is reported in one of the drywells it appears there are only two reasonable explanations. Either the drywell is sitting on the edge of a high-activity Cs-137 plume or the contamination was the result of a nuisance contamination spread. Distinguishing between the two options requires an assessment of other information such as waste transfer and waste level records, waste type in the tank, documented leak history, and data from nearby drywells.

### **3.1.2 Gross Gamma Logging Data and Synthesis with Spectral Gamma Logging Data**

Because gross gamma logging was conducted over two decades, evaluating these data provides information on the time-dependent behavior of the gamma-emitting radionuclides in the subsurface. The concentrations of the individual gamma-emitting isotopes that contributed to the gross gamma curves over time were estimated using the recently collected spectral gamma data (concentrations of specific gamma-emitting radionuclides) from the drywells used to collect gross gamma data. By factoring in decay, these calculated curves were propagated over time and compared with the gross gamma curve histories. Using this process, changes in the curves

caused simply by decay can be distinguished from decay plus changes in gamma radionuclide concentrations at a given location over time.

Appendix E summarizes the results for the C, A, and AX Tank Farms. The summary figures (Figure 2-1 for each tank farm) indicate which drywells contain gamma-emitting radionuclides and which do not. Of particular interest are the drywells indicating a change in radionuclide concentrations at a given location over time that cannot be attributed solely to radioactive decay. These conditions are referred to as unstable events. For each location, the borehole number, the depth below the surface, the radionuclide present, the time over which changes in concentration were deduced, and the concentration increase or decrease over that period are listed.

Near-surface changes bgs are attributed to tank farm operations and are broken out separately from changes that occur at greater depths. Changes at depth are attributed to tank and transfer line leaks of tank waste. The changes in radionuclide concentration over time in the C, A and AX Tank Farms attributed to tank farm activity are listed in Table 3-1 in all three tank farm discussions. These changes occur within 30 ft (9 m) of the surface and generally occurred from 1975 to 1985 over most of the tank farm areas. This observation is consistent with a common drywell spectral gamma pattern in which a maximum radionuclide concentration (usually  $^{137}\text{Cs}$ ) of 10 pCi/g to 100 pCi/g or occasionally higher near the surface diminishes with depth to about 1 pCi/g with depth. We consider this pattern to be consistent with surface or near-surface leaks of contaminated fluid.

The remainder of the radionuclide migration events (e.g., referred to as unstable zones and listed in Appendix E, Table 6-1 in the C, A, and AX discussions) occurs at depths near the tank bottoms or lower. Over the time during which measurements were taken, unstable conditions are observed in 19 drywells in the C farm, 4 drywells in the A Tank Farm, and 7 drywells in the AX Tank Farm. The majority of unstable zones in the C Tank Farm are associated with the transfer line leaks between tanks C-104 and C-105 and between tanks C-108 and C-109. Most involve movement of Co-60 after leakage from the transfer lines. Four of the five unstable zones in the A farm are associated with the transfer line leaks between tanks A-101 and A-102. The fifth measured instability is probably associated with the tank A-105 leak. The unstable zones in the AX Farm appear to be associated with transfer line leaks.

### **3.2 TANK WASTE CHEMISTRY AND LEAK CHARACTERISTICS OVERVIEW**

Environmental impacts of leaks from single-shell tanks or other waste loss events are closely linked to the type of waste lost to the soil column. Waste types stored in C farm tanks covered the complete range of waste types produced in the 200 Area chemical process facilities. The waste types stored in A and AX farm tanks tended to be less diverse, mainly PUREX high-level (boiling) wastes. The waste chemistry associated with the C farm is discussed first, then the A and AX farms.

As noted in Chapter 2.0, the C farm tanks began receiving wastes from the B Plant bismuth phosphate process in 1946. The high activity waste stream coming from the bismuth phosphate process contained essentially of the uranium by-product and the vast majority of the fission products (Serne et al 2003). This stream was called "metal waste". The first six tanks in the

C farm were filled with metal waste. The metal wastes were later recovered from the tanks and processed for uranium recovery in the U Plant in 200 West Area. The other six tanks in the C farm tanks were filled with so-called 1<sup>st</sup> Cycle waste, a much more dilute waste stream coming from the first plutonium dissolution/re-precipitation purification step. Cladding wastes were also added to these tanks. The cladding waste stream originated from the dissolution of the aluminum cladding from the fuel rods with a caustic nitrate solution and was a low activity stream. The 1<sup>st</sup> Cycle waste carried approximately 10% of the beta activity but a much lower fraction of fission products (Serne et al 2003). The cladding waste would have been a high aluminum, high hydroxide stream with low activity levels.

The uranium recovery process produced a waste stream at twice the volume of the metal waste recovery processed. This waste stream, called TBP or UR waste, was transferred back to a number of the C farm tanks. To free up tank space, the 1<sup>st</sup> Cycle wastes from C tanks were transferred to the B Evaporator. At a later date, the TBP wastes stored in C farm tanks was processed through for reduction of Cs-137 activity in the C Vaults. After allowing some time in C farm tanks for precipitation of resulting solids, the scavenged TBP waste was sent to the BC cribs and specific retention trenches. The 1<sup>st</sup> cycle wastes were later transferred to the B Evaporator. As C Farm tank space became available it was used to support pilot-plant studies at the Hot Semiworks and for low activity waste streams from PUREX. By the mid 1960s C Farm, tanks were being used to store aged PUREX high-level supernatants. As the B Plant isotope recovery process came online in 1968, several C farm tanks were used as feeder tanks supporting specific B Plant operations. Thus, many of the C farm tanks had very large volumes of wastes moved through them. The A Tank Farm, constructed in 1955, was used primarily to store PUREX high-level wastes. It was operated as a "boiling waste" tank farm with three laterals installed under each tank for leak detection. The four-tank AX farm was constructed in 1963 and 1964 and served the same purpose as the A farm tanks.

The high-level wastes coming from PUREX were very high-activity waste streams that were stored on the A and AX Tank Farms. After 3 to 5 years ageing, these wastes were transferred to other single-shell tanks to wait processing through B Plant. Waste streams coming from B Plant had reduced levels of Cs-137 and Sr-90 but also included additional organic completing agents.

The transfer of wastes through the C, A, and AX tanks are well documented in *Waste Status and Transfer Summary* (Agnew et al 1997) and *A History of the 200 Area Tank Farms* (Anderson 1990) and tank waste compositions are available from a number of sources, such as *Hanford Tank Chemical and Radio nuclide Inventories: HDW Model* (Agnew 1997), *Waste Management Technical Manual* (Buckingham 1967), and *B Plant Phase III Flow sheets* (Larson 1967). When tank waste loss events are well defined in terms of timing and volume, the inventory estimates for the lost materials are reasonably straightforward. However, the volumes of waste lost to the C and A-AX WMA vadose zone in various events are highly uncertain or unknown. Except for the tank A-105 leak no detailed analysis of known or suspected losses has been done in these tanks. Thus, inventory estimates for most waste loss events associated with the C and A-AX WMAs involve considerably uncertainty. Available information on specific leak events is provided in Section 3.3. Preliminary inventory estimates are provided in Section 4.3.

### 3.3 C AND A-AX WMA TANK WASTE LOSSES EVENTS

The *Waste Tank Summary for Month Ending December 31, 2002* (Hanlon 2003) lists three primary tanks and all four secondary tanks in the C Tank Farm, three tanks in the A Tank Farm, and two tanks in the AX Tank Farm as “confirmed or assumed leakers.” Estimated leak volumes vary from 350 gal in secondary tank C-204 (1300 L) to a possible 277,000 gal (1,050,000 L) in tank A-105. None of estimated leak volume are well constrained. In addition to these a number of transfer line leaks have been reported as unplanned releases (see Section 2.1.2 and Appendices A and B). Each of the listed leaks is discussed below to determine the severity of the contamination. In addition, the validity of the leak designations was critically reviewed to determine if the observed contamination is significant enough to support the leaker designation and warrant further characterization. A number of tanks are listed as confirmed or suspected leakers by Hanlon (1999), but neither the waste transfer record nor the gamma logging data support the designation.

Some additional locations were also considered because spectral gamma logging data indicates sufficient contaminant concentrations to warrant evaluation. These sites have not been clearly identified in the past as vadose contamination zones.

#### 3.3.1 C Tank Farm

Three of the twelve primary tanks in C Tank Farm (C-101, C-110 and C-111) and all four secondary tanks (C-201 through C-204) are listed in Hanlon (2003) as leakers. Of these, reliable leak estimates are available for none of the tanks. Evidence of tank waste losses to the vadose zone in these locations and other locations indicated by spectral gamma data are summarized below.

In addition to tank leaks, leaks from other infrastructure and tank farm activities occurred. An overall assessment of the spectral gamma logging data from C farm drywells indicates that most vadose zone contamination originated from surface or near surface sources. This is demonstrated by relatively high concentrations of Cs-137 near surface and a general decrease in Cs-137 activity with depth. Cobalt-60 is found near the bottom of many of the drywell with near surface Cs-137 contamination. This indicates that “mobile” Co-60 was driven down from recharge. These ubiquitous contamination events were not generally associated with particular recorded events and are not considered to be significant sources of vadose zone contamination. Those near surface contamination zones that are more concentrated are discussed in Section 3.3.1.2.

**3.3.1.1 Tank Waste Losses from C Farm Tanks.** Hanlon (2003) lists tank C-101 as a “known or suspected leaker” with a leak volume estimate of 20,000 gallons. Decreases in waste levels were documented in the late 1960s, a time when this tank contained aged PUREX high-level supernatant. A 20,000 gallon loss of this waste type would have released ~127,000 curies of Cs-137 (Simpson et al 2001), more than all of the Cs-137 projected to have been lost from all of the SX Tank Farm leaks (Jones et al 2000). The spectral gamma logging data from drywells around tank C-101 show little evidence of any leaks and certainly nothing of that order of magnitude. A far more likely scenario is the liquid level drops in the late 1960s were associated

with evaporation caused by the continuing high heat load of the aged PUREX high-level waste supernatants. The waste loss in the late 1970s appears to have been associated with saltwell pumping (Agnew et al 1997). Although the waste transfer records indicate that tank C-101 was filled above the 530 kgal fill limit from 1964 through 1969, there is no evidence of leaks from the spare inlet ports in this tank.

Spectral gamma data in two drywells around tank C-101 suggest small waste loss events may have occurred. In drywell 30-01-09, a Cs-137 peak (about 600 pCi/g) occurs about 28 ft bgs along with traces of Co-60, Eu-152 and Eu-154. The position of this peak suggests a small isolated leak from piping or a spare inlet port at this location. Tank waste chemistry suggests that Cs-137 in tank waste would be sorb readily on the soil and therefore, the leak location should be near the drywell. Because the peak value is low, it is concluded a substantial inventory was not associated with this leak. A second small tank leak may be indicated near drywell 30-01-06 where an apparent Cs-137 peak (about 50 pCi/g) around 40 ft bgs occurs, a depth that coincides with the tank bottom. Randall and Price (2001a) identified some instability in the gross gamma logs from 1979 to 1980 in this drywell at 30 to 41 ft bgs and interpreted the data as an indication of Cs-137 movement.

Hanlon (2002) lists tank C-110 as a known or suspected leaker. However, a detailed analysis of the history of the C Tank Farm (Agnew 1993) attributed liquid level decreases in 1969 to measurement errors and recommended the "leak status" of this tank be revisited. This analysis reaches similar conclusions. The spectral gamma logging data and historical waste transfer records provide no definitive evidence of leaks from this tank. The simplest explanation of spectral gamma logging in drywells around this tank is that the widespread surface contamination found its way down the inside or outside of well casings, likely from additions of water to suppress airborne transport of radionuclides.

At tank C-110 small concentrations of Cs-137 are found almost continuously in drywell 30-10-02 between the surface and 63 ft (19 m) bgs. The shallow contamination likely represents surface spills or shallow pipeline leaks (the cascade line between tanks C-110 and C-111 plugged in 1952 [Brevick 1994]), but the contamination between 44 and 63 ft (13 and 19 m) bgs may indicate the occurrence of a small leak. Cs-137 contamination was measured when the drywell was constructed in 1974, indicating the occurrence of a leak prior to this date. If a small leak did occur, the low Cs-137 concentration (maximum of 20 pCi/g) and the historical record of relatively dilute tank waste (first cycle waste, PUREX coating waste, organic wash waste) indicate that little contamination would have been released to the vadose zone. Very small concentrations of Cs-137 (< 1 pCi/g) were also measured on the west side of tank C-110 in drywell 30-10-09 between 17 and 38 ft (5 and 12 m) bgs. Contamination at this depth range may indicate a small transfer line leak. In addition, historical gross gamma records for 30-10-09 show a decrease of Ru-106 between 1975 and 1978 followed by an increase between 1978 and 1980 at tank bottom depth (40-60 ft (12 to 18 m) bgs). These data may be another indicator of this leak.

There are no spectral gamma data or well-documented historical record data suggesting leaks occurred at primary tank C-111 and secondary tanks C-201 through C-204. The *Waste Storage Tank Status and Leak Detection Criteria* document (Welly 1988) reported a liquid level drop in 1968 as the basis for questioning the integrity of tank C-111. However, the reliability of this

claim was not well-documented (DOE-GJO 1998b) and no spectral gamma data from drywells around the tank indicate loss of tank waste. No drywells are present near the secondary tanks and therefore no means of identifying leaked tank waste is available. In addition, no clear indication of tank leakage has been reported. However, given their small volume, it is concluded that no significant tank waste loss from this tanks has occurred.

Spectral gamma data strongly indicate that tank C-105 did leak, at least temporarily and the leak event is indicated by contamination observed at drywell 30-05-07 where two high Cs-137 concentration zones occur at and below the tank bottom. Between 34 and 44 ft (10 and 13 m) bgs and 48 and 62 ft (15 and 19 m), maximum Cs-137 values ( $10^7$  pCi/g and  $10^5$  pCi/g, respectively) were recorded (DOE-GJO 2000a). The general location and profile of the spectral gamma logging data indicate that tank C-105 likely leaked near the bottom on the southwest side very near drywell 30-05-07. The gamma contamination was encountered when drywell 30-05-07 was drilled in 1974. The historical gross gamma data analysis indicates no changes in location or intensity of Cs-137 activity. Thus, if tank C-105 did leak then the leak occurred prior to 1974 and apparently self-sealed because tank C-105 was used as an active Cs-137 recovery feeder tank until 1978. The Cs-137 recovery wastes were aged PUREX and REDOX high-level wastes so any waste losses would have contributed radionuclides to the soil column.

Concerns about the integrity of tank C-105 are supported by the historical record of large liquid level drops (about 36 in) in tank C-105 between 1963 and 1967 (DOE-GJO 1997b). However, during the time tank C-105 stored aged PUREX high-level waste supernatant, liquid losses to evaporation are noted in the historical records (Agnew et al 1997). The contamination in the region between tanks C-104 and C-105 has been of interest (Brodeur 1993, Agnew 1993). Both cascade line and spare inlet port waste loss events have been suggested as sources of contamination in this region.

An alternate explanation for the high activity in drywell 30-05-07 has been given. It is suggested that Cs-137 in this drywell has origins in the cascade line between tanks C-104 and C-105 (Brodeur 1993). However, the likely waste, PUREX supernate, does not appear to have the appropriate chemical makeup to mobilize Cs-137 in the soil column. Therefore, a leak source at the tank wall two feet from the contaminated zone compared to the cascade line more than thirty feet away is much more plausible. The two high Cs-137 zones may indicate two leak events.

In addition to Cs-137 contamination at the tank bottom, isolated occurrences of Co-60, Eu-152 and Eu-154 are present. The true extent of these contaminants at this drywell location is difficult to determine. The very high Cs-137 concentrations may mask the occurrence of these isotopes at the same depth. In addition, the drywell ends at about 68 ft (21 m) bgs and additional contamination at greater depth cannot be determined.

Two other drywells may indicate the outer edges of the proposed tank C-105 leak. In drywell 30-05-05 just south of drywell 30-05-07, a Cs-137 peak (about 70 pCi/g) occurs between 60 and 65 ft (18 and 19 m) bgs and a Co-60 peak occurs at 70 ft (21 m) bgs. Proximity of the two drywells and consistent Cs-137 peaks with depth suggest the same leak source. Similarly, a Cs-137 peak (15 pCi/g) occurs at 47 ft (14 m) bgs in drywell 30-05-08. Co-60 is also present between 35 and 50 ft (11 and 15 m) bgs



**3.3.1.2 Other Contamination Zones in the C WMA.** Near surface contamination events are indicated at other locations within the C WMA by historical records, field investigations and drywell spectral gamma data. Unplanned releases in the C WMA, near surface transfer line leaks and generalized surface contamination are all indicated by this information. The most contaminated sources are discussed in greater detail below. Three significant unplanned releases that occurred to the west of C Tank Farm but still within the C WMA are described in this section. Within the C Tank Farm, spectral gamma measurements have been recorded at many drywells in the eastern half of C Tank Farm, particularly the southeastern segment. Cesium-137 and Co-60 are the most prominent contaminants and given the relative concentrations of these constituents, two locations appear to be the primary source of this contamination, these being the areas between tanks C-104 and C-105 and between tanks C-108 and C-109.

**3.3.1.3 Unplanned Releases in the C WMA.** Williams (2002) identifies a number of unintentional near-surface losses and windblown contamination events in the C Tank Farm. The Waste Information Data Base System (WIDS) summarized these events, also known as unplanned release events (UPRs). The *Handbook 200 Area Waste Sites* (Maxfield 1979) also discusses some events. Two of the UPRs (UPR-200-E-82, and UPR-200-E-86) involved PUREX high-level waste supernatant and contributed significant inventory to the soil column. A third UPR involved the loss of PUREX aluminum cladding waste. These three events occurred on the southwest side of the C Tank Farm and made relatively significant contributions to vadose zone contamination. The WIDS also identifies a number of other waste loss events but these involve either small (less than 100 gal) volume losses, airborne contamination spreads, or tank leak information mirroring the information in the monthly Hanlon report *Waste Tank Summary for Month Ending October 31, 2000* (Hanlon 2000). There is small overland piping leak (50 gal) involving the loss of PUREX cladding waste between tanks C-105 and C-108, documented in UPR-200-E-16. The spectral gamma logging data (DOE-GJO 1998a) for the C Tank Farm indicates widespread low-level Cs-137 contamination across much of this farm.

Report UPR-200-E-81 describes a 1969 waste loss event that occurred near the 241-CR-151 Diversion Box and involved the loss of 136,000 L (36 Kgal) of PUREX cladding waste (Williams 2001, Maxfield 1979). A puddle of contaminated liquid measuring 6 ft by 40 ft was formed. The puddle was backfilled with clean dirt in 1969. The PUREX cladding waste was a reasonably low activity waste stream produced from the caustic dissolution of the aluminum fuel rod cladding. The origin of the radioactive contamination in this waste stream was congruent dissolution of the uranium fuel during the de-cladding operation. It was estimated that 720 Ci of Cs-137 were lost to the soil.

Report UPR-200-E-82 describes the loss of Cs-137 Recovery Process feed solution being pumped from tank C-105 to the B Plant. The leak occurred near the 241-C-152 Diversion Box and involved the loss of approximately 2,600 gallons of liquids (Tanaka 1971). Approximately 100 gallons of this fluid surfaced. Surface contamination was covered with clean gravel in 1969. This waste loss event was thoroughly investigated and results are available in *B Plant Ion Exchange Feed Line Leak* (Tanaka 1971). It was estimated that 11,300 Ci of Cs-137 were lost to the soil. Additional inventory estimates of vadose contamination from this event are discussed in Chapter 4.

Report UPR-200-E-86 describes a waste loss event associated with a pipeline break near the southwest corner of the C Tank Farm. Fluids were being pumped from the 244-AR Vault to the C Tank Farm. Approximately 17,400 gal of fluid that contained approximately 25,000 Ci of Cs-137 were lost to the soil (Maxfield 1979). Based on the ratio of Tc-99 to Cs-137 in the irradiated fuel ( $\sim 3 \times 10^{-4}$  Ci Tc-99/Ci Cs-137), approximately 7.5 Ci of Tc-99 were lost. This waste stream most likely originated from the water washing of PUREX sludge intended to remove Cs-137 (and other waste soluble components) from the sludge prior to acidification and Sr-90 recovery.

**3.3.1.4 Near Surface Contamination in the C WMA.** Generalized near-surface contamination occurs across the C Tank Farm and probably in other parts of the C WMA. About a dozen of the drywells in the farm have Cs-137 gamma activity that peaks at or above 100 pCi/g in the upper 15 feet of the vadose zone, however, most contaminated drywells are around 10 pCi/g. Two of these higher concentration zones, between tank C-104 and C105 and between C-108 and C-109, apparently are caused by small transfer leaks.

Between tank C-104 and C-105, a Cs-137 (531 pCi/g) peak at about 24 ft (7 m) bgs in drywell 30-04-03 indicates a transfer line leak. Apparently the Cs-137 was present before 1974 (Welty 1988). Below the Cs-137 peak, a Co-60 contamination zone (3–6 pCi/g) occurs from 26 ft (8 m) bgs to the bottom of the drywell (about 50 ft (15 m) bgs). Drywell 30-04-02 also includes Cs-137 and Co-60 contamination at similar depth ranges but the Cs-137 peak is not evident, suggesting that drywell 30-04-03 is closest to the source. In addition, Co-60 appears at a slightly greater depth interval between 40 and 60 ft (12 and 19 m) bgs in drywell 40-04-02. Historical gross gamma data indicate Co-60 movement for at least ten years beginning in 1975 when well-documented measurements were first taken. Drywell 30-04-01, which contains Cs-137 contamination almost continuously between the surface and the drywell bottom at 50 ft (15 m) bgs, may also have seen contaminant movement since 1975.

Third, a Cs-137 and Eu-154 peak (about 70 and 20 pCi/g, respectively) occurs in drywell 30-05-08 at 17 ft (5 m) bgs. This may or may not be the same transfer line that leaked near drywell 30-04-03. However, the fact that Eu-154 is present in this drywell and not in drywell 30-04-03 suggests somewhat different waste stream chemistry. No other contiguous drywells show this pattern.

Between tanks C-108 and C-109, a transfer line leak source is indicated by contamination in drywell 30-08-02. High Cs-137 concentrations occur between 20 and 22 ft (about 6 m) bgs and peak at 1,100 pCi/g in this zone. A Eu-154 peak (24 pCi/g) is coincident with Cs-137 and the more mobile Co-60 is present between 50 and 80 ft (15 and 24 m) bgs at concentrations up to 10 pCi/g. These contaminants were present when the drywell was installed in 1974. This contaminant plume appears to extend at least to drywell 30-06-10 where a similar Co-60 plume occurs between 86 and 115 ft (26 and 35 m) bgs at lesser concentrations (up to 1 pCi/g). Co-60 also occurs to a lesser degree in drywell 30-09-01 at 90 to 95 ft (27 to 29 m) bgs. This location may represent the eastern extent of this contaminant plume. Other nearby drywells may also contain contamination that has migrated from this transfer line. These drywells (30-09-06, 30-09-07 and 30-09-02) along with drywells 30-08-02 and 30-06-10 contain mobile Co-60 that migrated in the 1980's between 40 and 115 ft (12 and 35 m) bgs according to the gross gamma record. The apparent lag time between initial discharge to the vadose zone before 1974 and the

observed Co-60 migration in the 1980s may indicate additional leakage or enhanced migration instigated by artificial discharge.

Numerous drywells in the east and southeast part of the tank farm other than those listed above contain Cs-137 primarily between the surface and tank bottom depth of about 40 ft (12 m) bgs and Co-60 that is located well below tank bottoms (80 ft [24 m] bgs and deeper) and has migrated during the course of the gross gamma logging program between 1975 and 1994. Generally speaking it appears that Co-60 migrates towards the east or southeast in the C WMA vadose zone, judging by the overall Co-60 distribution in the C Tank Farm drywells. The source of contaminants in the vadose zone may be related to the transfer line leaks, the proposed tank C-105 leak or unidentified leaks. However, when the transfer lines and tank C-105 are postulated as sources of the Co-60, contamination at specific drywells cannot be connected readily to these specific sources.

One other possible source is tank C-103. Two drywells (30-03-01 and 30-03-07) show small Cs-137 peaks around 50 ft (15 m) bgs that might indicate a tank leak. In addition, extended Co-60 contamination zones (20 ft (6 m)) occur in drywells 30-03-01 and 30-03-09 below 80 ft [24 m] bgs. However, these data do not clearly indicate a leak event. The Cs-137 data at drywell 30-03-01 is ambiguous because this drywell was completed in two stages and substantial Cs-137 contamination existed near the surface. During the second stage deepening of the drywell an opportunity presented itself for dragdown contamination in the depth range containing elevated Cs-137 concentrations. In drywell 30-03-07 the lack of a Co-60 contamination zone below the Cs-137 is unexpected if a tank leak occurred here and other surrounding drywells include Co-60 as a contaminant deeper in the vadose zone.

Finally, a small pipeline leak on the north side of tank C-112 is indicated by a thin high Cs-137 concentration zone at 8 ft (2 m) bgs in drywell 30-12-13. Lesser concentrations of Cs-137 (about 1 pCi/g), Co-60 and Eu-154 are found lower in the soil column (down to 50 ft (15 m) bgs).

### 3.3.2 A Tank Farm

Three of the six tanks in the A Tank Farm (A-103, A-104 and A-105) are listed in *Waste Tank Summary Report for Month Ending February 28, 1999* (Hanlon 1999) as leakers. Reliable leak estimates are available for none of the tanks. Evidence of tank waste losses to the vadose zone in these locations and other locations indicated by spectral gamma data are summarized below. Other areas of significant near surface contamination are discussed in Section 3.3.2.2.

**3.3.2.1 Tank Waste Losses from A Farm Tanks.** Spectral gamma measurements have been recorded in drywells around the A farm tanks and in laterals placed horizontally (about 10 ft [3 m] below the tank bottom) underneath each of the tanks. Historical reports (Welty 1988) identify an increase in radiation measured at the bottoms of drywells 10-03-01 and 10-03-07 (75 ft [23 m] bgs) in 1964 and in 1968 at drywell 10-03-07. Current spectral gamma data show little or no contamination at these locations. Spectral gamma data for several drywells (10-03-01, 10-03-05, 10-03-07, 10-02-03, and 10-03-11) around tank A-103 measure small amounts for Cs-137 (about 0.1 pCi/g) at 80 ft (24 m) bgs and below. All of these wells were drilled in two stages, first to 75 ft (23 m) bgs and then further down. This history combined with

the very low measured values strongly indicates dragdown of any Cs-137 that might be present at depth. Given the lack of convincing evidence it is concluded that either tank A-103 did not leak or did not leak sufficiently to contaminate the vadose zone to any significant degree.

The primary evidence of tank waste leaks from tank A-104 is provided by measurements of increased radiation in two laterals underneath the tank in 1975, first in lateral 14-04-02 in the north central part of the tank and then in the southeast section in lateral 14-04-02. Eventually, radiation was measured in the third lateral as well. Evaluation of the gross gamma logs (Randall and Price 2001b) shows Ru-106 as a primary gamma emitter. The variable locations of radiation detection under the tank may indicate multiple leak locations. However, the extent of contamination that has actually entered into the vadose zone is quite limited given the lack of contamination in adjacent drywells. Spectral gamma data show no significant contamination at tank bottom depth.

Structural failure of tank A-105 is well documented (Caggiano 1991, WHC 1991, Beard et al. 1967). In January 1965, a sudden steam release occurred in tank A-105. Steam was released from a riser on an interconnected tank, A-103. The steam release event lasted for 30 minutes. Significant damage occurred to the bottom of the steel liner during the steam release event. It was estimated that, at most, 4 inches of liquids had been lost from tank A-105. Within a couple months, increased activity was measured in lateral 14-05-03 in two places on the east and north side of the tank. Subsequently, additional risers were drilled through the tank dome and the tank interior was inspected, revealing a significant section of the liner floor that had bubbled up and partially separated from the sidewall. Despite the obvious liner failure, it was determined that the tank was not leaking. No significant gamma activity was measured in the surrounding drywells suggesting that the concrete tank structure provided adequate containment for the tank fluids.

The tank was closely monitored until the tank contents had aged sufficiently to allow the supernatant to be sent to B Plant for Cs-137 recovery. Most of the PUREX sludge was sluiced from the tank, however, a high-heat hard heel was left in the tank. Consequently, water was added to the tank contents for cooling for the next eight years. Hanlon (2002) listed an estimated leak volume for tank A-105 as 10,000 to 277,00 gallons. The 10,000 gallons represents the upper limit of the volume of tank waste lost during the initial steam release event. The additional volume represents cooling water that may or may not have leaked from the tank during the eight years of water addition. The lack of significant gamma reading in nearby drywells strongly indicates the volume estimate of 10 kgal to be extremely conservative. Liquid volume lost associated with the 30-minute steam release event is unknown but could have accounted for all of the liquid loss from this tank.

Over time, additional lateral measurements of increased activity did occur in other laterals, which could have indicated additional leak locations or spreading from the initial leaks. The current spectral gamma database continues to show minimal tank waste contamination in the vadose zone (DOE-GJO 1998c). Cesium-137 concentrations have been measured at several drywells (10-05-02, 10-05-05, 10-05-07, 10-05-09, 10-06-09 and 10-05-12) at the tank bottom and lower depths. However, many of these drywells were constructed in two stages and dragdown contamination is likely in most of them. One drywell (10-05-10) may contain Cs-137 contamination from the A-105 tank leak (between 75 and 86 ft (23 and 26 m) bgs) but the

complicated drilling process may have shifted the Cs-137 from its original location. The historical gross gamma log shows a shift in Cs-137 contamination levels around 1978 but this is probably related to the second stage drilling that occurred then.

**3.3.2.2 Additional A Tank Farm Contamination.** The only other area of significant vadose zone contamination indicated by spectral gamma data in the A Tank Farm is a small area between tanks A-101 and A-102. In this area, subsurface contamination levels exceed those around the tanks that have leaked in the A Tank Farm. Historical records and the spectral and gross gamma data indicate a complicated tank waste release history. At least two leak sources appear to be indicated as well as enhanced recharge that occurred from leaking water lines in the vicinity. The first source appears to be leaking pipes at the 241-A-01B sluice pit at the southeast side of tank A-101. Occurrence Report 81-03 by Lindsay (1981) reports the drilling and sampling of several boreholes (not the current drywells) on top and at the periphery of the tank dome between the sluice pit and drywell 10-01-04. The boreholes near the sluice pit were reported to contain Cs-137 and those at the periphery contained C-60 and Ru-106. Two drywells 10-01-03 and 10-02-08 contain 2 ft (1m) zones of very high Cs-137 concentrations around 5 ft (2 m) bgs. Given the general reactivity of Cs-137, these sites are unlikely to contain Cs-137 that migrated from the sluice pit. The source of additional leaks is probably a shallow pipeline or multiple pipelines. Neither the time of the leaks nor the leak volumes are known.

Just south of these locations are a group of four drywells (10-01-28, 10-01-39, 10-01-16 and 10-01-04) that include Cs-137, Eu-154, and Co-60 and show a contaminant distribution pattern at 30 ft (10 m) bgs and below suggesting a common source to the north, either the postulated sources described above or an additional unidentified source (e.g., a cascade line leak). All of these drywells show Cs-137 contamination between 0 and 20 ft (6 m) bgs and then increasing contamination at greater depth. Peak concentrations occur at the shallowest depth in drywell 10-01-28 around 25 to 30 ft (8 to 10 m) bgs. As the drywell locations move south the peak concentration depths deepen slightly and more reactive contaminations drop out (e.g., all three isotopes are present in drywell 10-01-28 and 10-01-39, only Co-60 is present at drywell 10-01-04).

### **3.3.3 AX Tank Farm**

Two of the four tanks in the AX Tank Farm (AX-102 and AX-104) are listed in Hanlon (2000) as leakers. Reliable leak estimates are available for neither of the tanks. The AX tanks had leak detection systems build into the tank bases and no data have been found that indicate any positive hits in these systems. Evidence of tank waste losses to the vadose zone in these locations and other locations indicated by spectral gamma data are summarized below.

The conclusion that tank AX-102 leaked was based on several occurrence reports beginning in 1975 of slight liquid level drops, slight increases in borehole activity and an increase in the leak detection pit activity. None of these occurrences were clear indicators of leakage. The most likely real leak event associated with the occurrence reports was loss from a coupling to an exhaust vapor header attached to the tank. The highest gamma contamination among the boreholes surrounding tank AX-102 occurs at about 12 ft (4 m) bgs in drywell 11-02-12 and has been attributed to this event. In this zone Cs-137 concentrations exceeded the detection limit and

Eu-154, Co-60 and Sb-125 are also present. Co-60 and Sb-125, being apparently more mobile than Cs-137 and Eu-154 are measured below the high concentration zone between 12 and 30 (4 and 10 m) bgs. Very small Cs-137 concentrations (about 2 pCi/g or less) occur between 50 and 70 ft (15 and 21 m) bgs at drywell 11-02-01 and between 30 and 50 ft (10 and 15 m) bgs at drywell 11-02-02. While this contamination may be an indicator of a small tank leak, it seems more likely that dragdown is the cause.

The conclusion that tank AX-104 leaked was based on several occurrence reports describing increased activity in nearby drywells and one liquid level decrease event. The gross gamma activity records measured increased activity around tank bottom level but were brief in duration and of poor quality. The spectral gamma data from surrounding drywells show no levels of elevated activity (DOE-GJO 1997c). Thus, if any leakage did occur it was not significant.

Two other locations in AX Tank Farm contain elevated concentrations of gamma emitting radionuclides. Between tanks AX-103 and AX-101 on the north side, a surface spill is indicated in drywells 11-01-10, 11-03-02 and 11-03-12 (DOE-GJO 1997d, 1997e). Drywell 11-01-10 is located closest to the source of the spill. Between 3 and 5 ft (1 and 3 m) bgs, a high Cs-137 concentration zone occurs (up to 4,000 pCi/g) at drywell 11-01-10. Cobalt-60 and Eu-154 were also detected between 5 and 15 ft. At drywell 11-03-02 elevated Cs-137 concentrations (up to 1,000 pCi/g) occur between the surface and 26 ft (8 m) bgs along with Co-60 and Sb-125. The edge of the spill may be indicated at drywell 11-03-12 where Cs-137, Co-60 and Sb-125 were measured between the surface and 10 ft (3 m) bgs.

The second location containing elevated gamma-emitting radionuclides occurs at the southwest side of tank AX-103 and northwest side of tank AX-104. Surface spills are again indicated by the intensity and distribution of gamma-emitting radionuclides at drywells 11-03-07 and 11-04-10 (DOE-GJO 1997c, 1997e). Elevated concentrations of Cs-137 (about 100 pCi/g), Co-60 (1 pCi/g) and Eu-154 (10 pCi/g) were measured between 5 and 8 ft (2 and 3 m) bgs at drywell 11-03-07. At drywell 11-04-10, Cs-137, (1450 pCi/g) Co-60 (5 pCi/g) and Eu-154 (22 pCi/g) peak about 5 ft (2 m) bgs. Contamination in these two holes may have resulted from the same discharge event or may indicate separate discharge events. Historical gross gamma data (Price 2001) indicate vertical migration of Ru-106 in boreholes 11-03-07 and nearby boreholes 11-03-09, 11-04-01 and 11-04-11 with all incidents occurring in the late 1970s.

### 3.4 CURRENT ASSESSMENT OF SINGLE-SHELL LEAK INFORMATION

The current status of tank leak information is summarized in Table 3-1 for the tanks in C, A and AX Tank Farms. All tanks listed as leakers in Hanlon (2002) and one additional tank, C-105, are listed Table 3.4-1. Concurrence or disagreement with the Hanlon report is indicated in the fourth column and reflects the evaluation provided in this report. Tank C-105 was added to the list because it was concluded to be a leaker in this evaluation.

The primary indicators of tank leakage are historical liquid level records for individual tanks and gamma logging data in drywells around tanks. Tank leaks are indicated by liquid level drops that clearly occurred and cannot be explained by liquid waste transfers and by the presence of gamma emitting radionuclides at appropriate depths and concentrations in the vadose zone near

tanks. A statement of no evidence for leaks indicates that the recorded liquid level drops, where available, were too uncertain to indicate tank leaks and gamma data showed little or no contamination that could be linked unequivocally to a leaking tank. In no case is the absolute integrity of any tank implied by this conclusion, but relative to further characterization and risk evaluation, these tanks are considered to be insignificant contributors to current vadose zone contamination.

Table 3-1. Tank Leak Information Summary

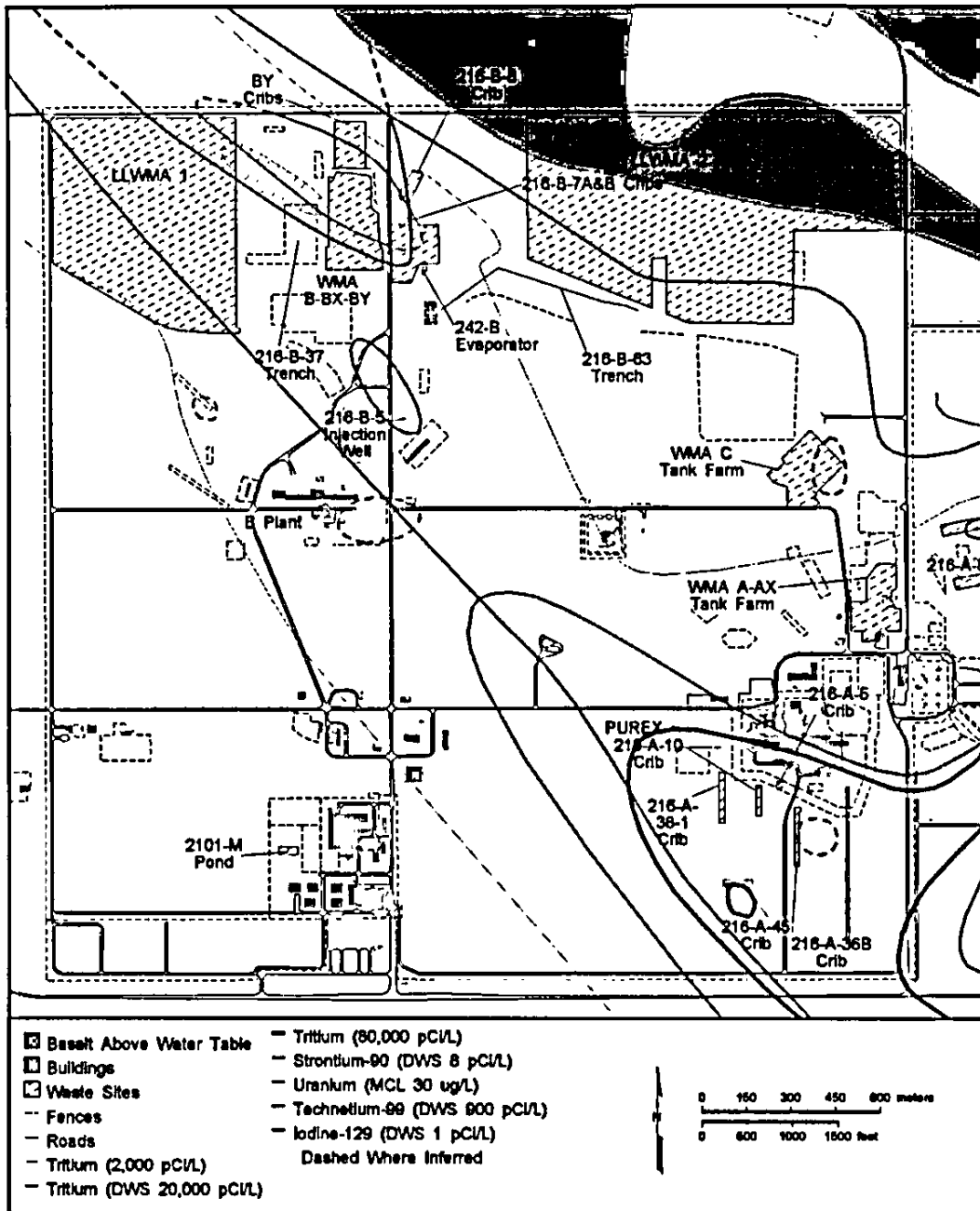
Tank	Listed in Hanlon Table-5	Hanlon Leak Volume (Gal)	Treated as Leaker Here	Volume Suggested
A-103	Yes	5,500	No evidence for leak	
A-104	Yes	500 to 2500	Yes	Inventory estimate assumes 2 Kgal
A-105	Yes	10K to 277K	Yes, but likely very small	Inventory estimate assumes 1 Kgal
AX-102	Yes	3,000	No evidence for leak	
AX-104	Yes	Not Reported	No evidence for leak	
C-101	Yes	20,000	No evidence for leak	
C-105	No	----	Early leak likely	Unknown but small Inventory estimate assumes 1 Kgal
C-110	Yes	2,000	No evidence for leak	
C-111	Yes	5,500	No evidence for leak	
C-201	Yes	550	No evidence for leak	
C-202	Yes	450	No evidence for leak	
C-203	Yes	400	No evidence for leak	
C-204	Yes	350	No evidence for leak	

### **3.5 GROUNDWATER CONTAMINANT INFORMATION**

This section covers the current state of groundwater contamination surrounding the A-AX and C WMAs, including historic constituent trends that depict the temporal and spatial distribution of contaminants. Several distinct suites of contaminants are recognized, based on spatial relationships and on identifying associations of co-contaminants or aqueous chemical parameters. Given the complicated history of waste discharge to the subsurface in the last 50 years combined with artificial reversals in the natural flow direction and the ambiguities and dynamics in the current flow direction (see B/BX/BY Field Investigation Report (FIR) for further information), identifying sources at this time is not possible. The current regional distribution of radionuclides (i.e., tritium, strontium, uranium, technetium, and iodine) in the groundwater in the 200 East Area is shown in Figure 3-1, and the nitrate and chromium distribution is shown in Figure 3-2. Near the C and A-AX WMAs, contaminant concentrations are moderate and there is no clear indication of vadose contamination within the WMAs being a source.

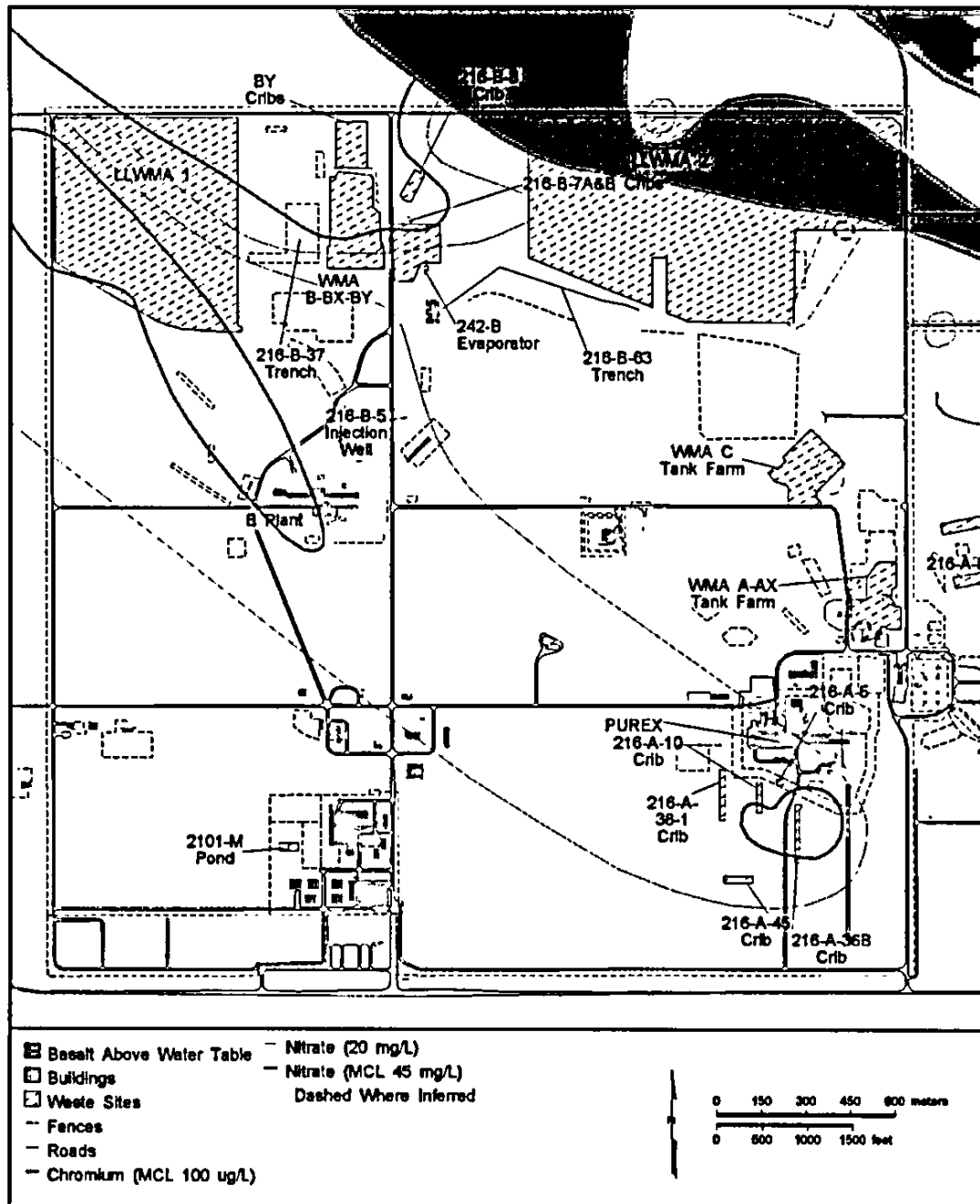


Figure 3-1. Distribution of Radionuclides in the Unconfined Aquifer in 200 East Area.



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**Figure 3-2. Distribution of Chromium and Nitrate in the Unconfined Aquifer in 200 East Area.**



### 3.5.1 Groundwater Monitoring Results Near the C WMA

Groundwater samples have been taken regularly from several groundwater monitoring wells around the C WMA since the early 1990s. These include monitoring wells 299-E27-13, 299-E27-12, 299-E27-15, 299-E27-7, and 299-E27-14. Recent chronological changes in key constituent values (pH, specific conductance, and technetium-99, nitrate, sulfate and chloride concentrations) are summarized below and illustrated in Figures 3-3 through 3-6.

Key constituent values remained essentially constant and at values below regulatory concern until the late 1990s, at which point some values began to increase. During fiscal year 2001, critical mean values from samples taken from groundwater wells monitoring the C WMA were not exceeded for the three indicator parameters of pH, total organic carbon, and total organic halides. However, the critical mean value for specific conductivity (553.3 uS/cm) was exceeded in well 299-E27-14 at the end of FY2001 (Figure 3-3). An averaged value of 614 uS/cm was reported for this cross gradient well for the September 2001 sampling event. The increase in conductivity is due primarily to rising sulfate and calcium along with nitrate and chlorine (Figure 3-4). Sulfate was 135 mg/L while nitrate was 29 mg/L for July 2001. The September 2001 sulfate data is abnormally low and is under review. The nitrate value for September 2001 is 43.8 mg/L, very close to the DWS of 45 mg/L.

Technetium-99 activities continue to increase in all wells at the C WMA (Figure 3-5). This technetium-99 contamination correlates to the rising anionic chemistry. Although downgradient well 299-E27-13 had a pulse of technetium-99 (487 pCi/L) seen in 1998, the recent technetium-99 contamination began to increase in the mid-1990s in well 299-E27-14, to a value of 1190 pCi/L in July FY2001. The greatest increase in FY2001 was detected in well 299-E27-7, which had a maximum value of 2190 pCi/L in July 2001 (DWS 900 pCi/L). The correlation of the nitrate to the technetium-99 is shown in Figure 3-6. As can be seen, nitrate is greater in well 299-E27-14 while technetium-99 is higher in well 299-E27-7. These reversals in concentration versus activity levels indicate contaminant contributions from multiple sources.

Figure 3-3. Trend Plots of Specific Conductance for C WMA.

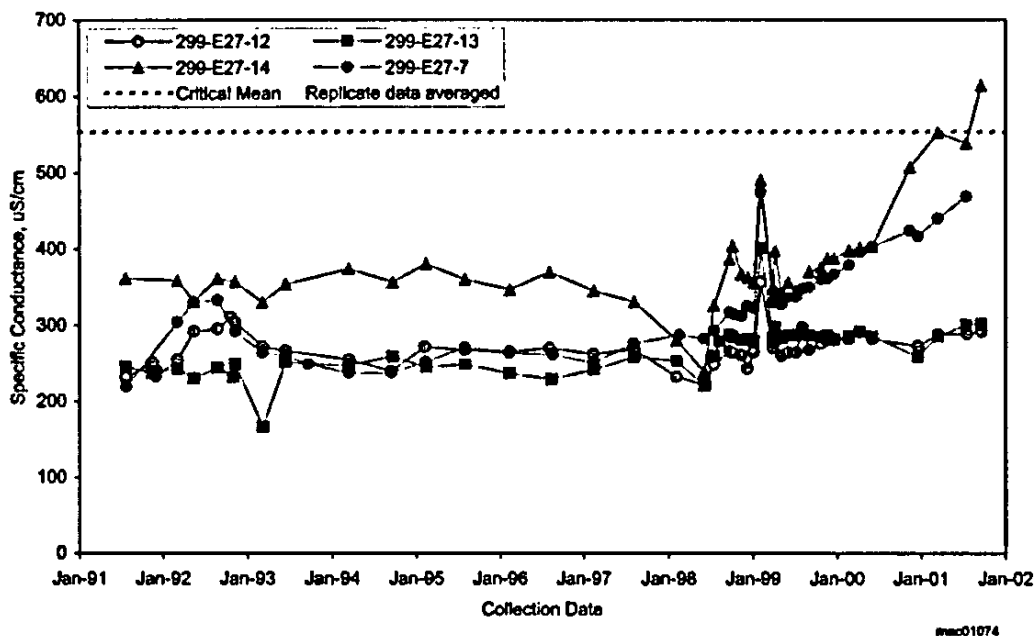
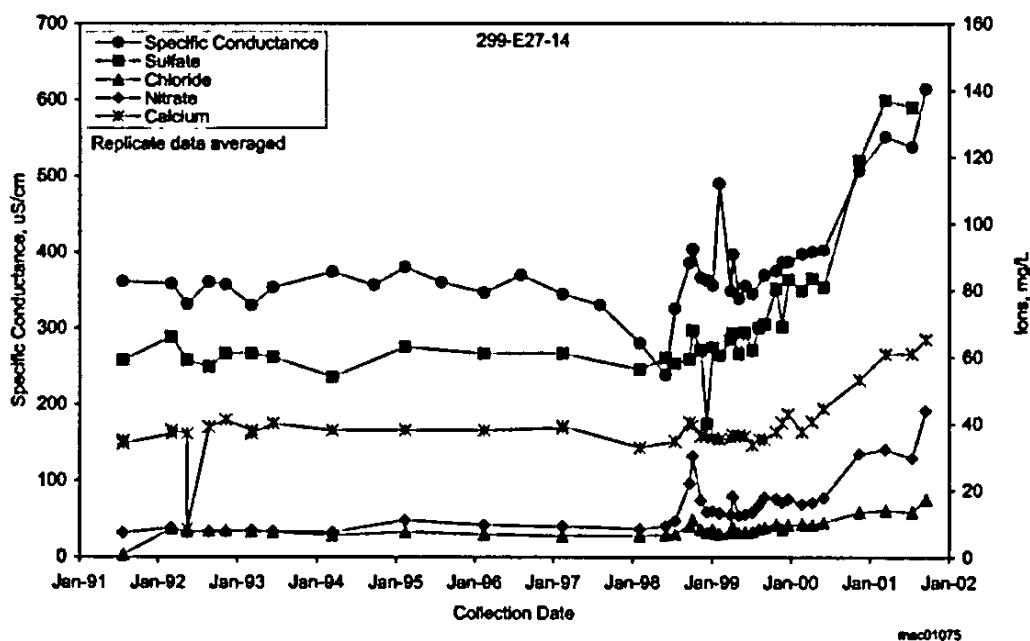


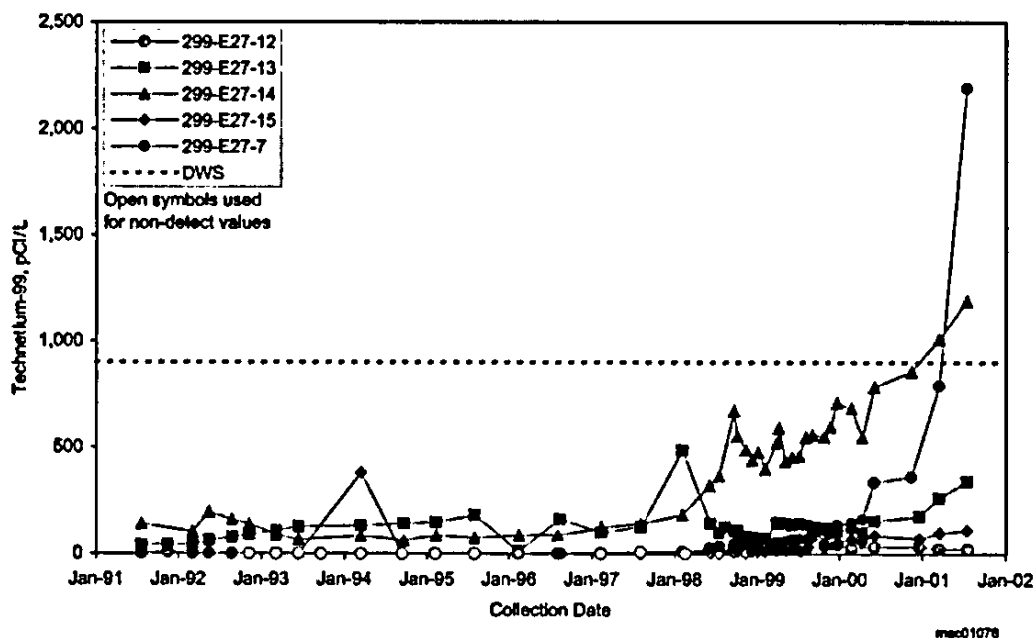
Figure 3-4. Trend Plots of Specific Conductance, Cations and Anions for Well 299-E27-14.

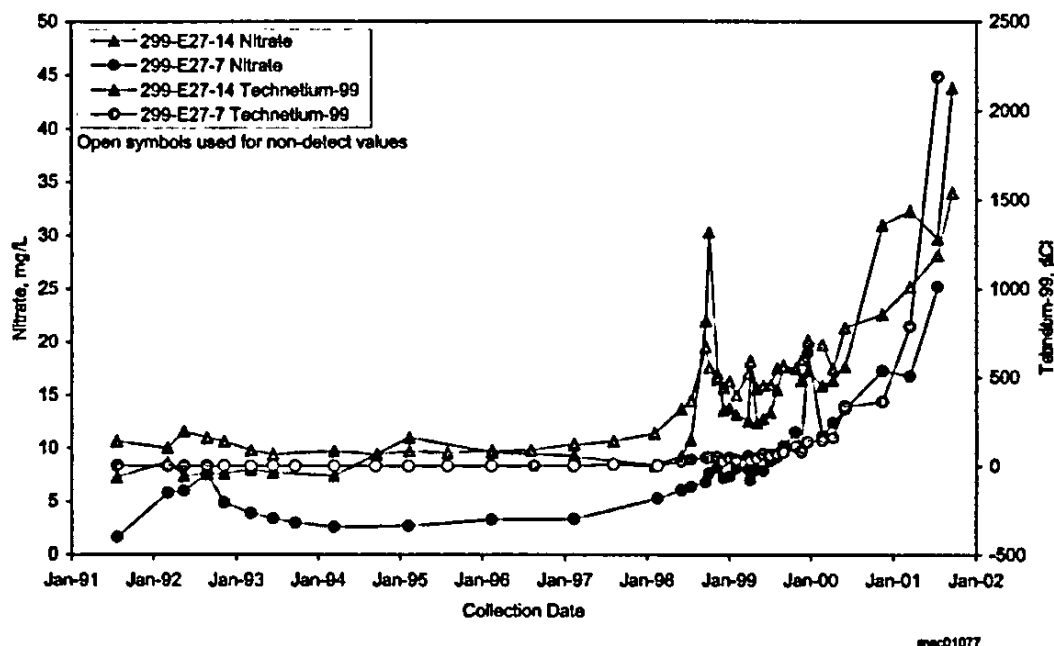


These increases in well 299-E27-14 are part of a contaminant plume that may be moving into the area from upgradient areas in recent years. Although the source of this contamination is presently unknown, it may be related to past discharges that moved through the area when the B Pond was in full operation or from the upgradient 216-B-3-1 ditch. As part of a continuous ditch system connected to the 216-B-63 Trench, this ditch was decommissioned in 1964 after an accidental release of mixed fission products from the PUREX Plant was discharged directly to the 216-B-3-1 Ditch (DOE 1993a).

The technetium-99 level in well 299-E27-7 rose quickly in 2001, which often indicates a nearby source. However, a plausible source is not readily identifiable. (e.g., the 216-B-3-1 ditch does not appear close enough to be the source of this groundwater contamination). Results from well 299-E27-7 have also shown low levels of cyanide with a maximum value of 17  $\mu\text{g/L}$  in June 2000. Ferrocyanide scavenging was conducted in the 244-CR Vault with storage in selected tanks at Waste Management Area C (Kupfer et al 1997). Although well 299-E27-7 is the upgradient well for this WMA, the only known sources for cyanide are the 244-CR vault and the waste stored in the C Tank Farm. Again, a readily identifiable source is not known. Cyanide concentrations decreased during FY2001, and presently cyanide is not detected in this well or any other network monitoring well.

Figure 3-5. Trend Plots of Technetium-99 for the C WMA.



**Figure 3-6. Trend Plots of Nitrate and Technetium-99 for the C WMA.**

There does not appear to be other tank-related waste in the groundwater at Waste Management Area C. Tritium levels are low, generally less than 1,500 pCi/L, except at well 299-E27-7 where values rose from about 600 to 2,500 pCi/L during the late 1990s. Currently, the trend remains steady near 2,480 pCi/L. Based on these measurements, C WMA still is not considered to be under RCRA corrective actions.

### 3.5.2 Groundwater Monitoring Results Near the A-AX WMA

Groundwater samples have been taken regularly from several groundwater monitoring wells around the A-AX WMA since the early 1990s. These include monitoring wells 299-E25-46, 299-E24-19, 299-E24-20, 299-E25-40, and 299-E25-41. Recent chronological changes in key constituent values (pH, specific conductance, and technetium-99, nitrate, sulfate and chloride concentrations) are summarized below and illustrated in Figures 3-7 through 3-13. Overall, these data provide no indication that vadose zone contamination in the A-AX WMA contributes to local groundwater contamination and hence this WMA is not under RCRA corrective action.

Key indicator values (specific conductance, pH, technetium-99 activity and nitrate, sulfate and chloride concentrations) have generally remained below regulatory triggers. Although concentrations of indicator parameters, conductivity, TOC and TOX have not exceeded the critical means at Waste Management Area A-AX since 1992, the pH fell below the critical range (6.89 to 9.24) in well 299-E24-19 in July 2001. This well is, at best, cross gradient as it is located on the southwest side of the WMA (see Figure 1-3). Verification sampling was conducted in October 2001 resulting in a pH value of 7.13. Causes for the low pH are discussed

below in relation to the elevated chromium found in the groundwater at this location. Specific conductance values generally ranged from 261 to 374  $\mu\text{S}/\text{cm}$  during fiscal year 2001 (Figure 3-7), reflecting changes in sulfate and nitrate concentrations. The primary cation is calcium. These specific conductance values are well below the critical mean of 534.9  $\mu\text{S}/\text{cm}$ . Figures 3-8 and 3-9 show trend plots for sulfate and nitrate, comparing contaminant levels in the A-AX WMA network groundwater monitoring wells. The specific conductance changes that occurred at the A-AX WMA are generally dominated by sulfate except for well 299-E24-20 (maximum contaminant level 250 mg/L). Although sulfate appears to be increasing in wells on the southwest side of the WMA, sulfate concentration ranges from 37 to 48 mg/L, which is within the Hanford Site background values reported in WHC-EP-0595 (~14 to 60 mg/L). Although in the past, sulfate concentrations above background values were identified in two wells, 299-E25-40 and 299-E25-41, the recent trend appears to be decreasing to values of 55 to 57 mg/L.

Nitrate values (Figure 3-9) have ranged from ~4 to 12 mg/L, which falls within the ranges of background values of 3 to 12 mg/L for the Hanford Site (Johnson et al 1993) except at well 299-E24-20 located west of the A Tank Farm and south of the 244-AR vault (see Figure 1-3) where anomalously high values have been measured. Nitrate concentrations about 45 mg/L occurred between 1992 and 1994 and then began to increase in 1996 and beyond to values above 30 mg/L. This well is upgradient of the A-AX WMA, suggesting an upgradient source for higher nitrate concentrations in this well. There is a good correlation with anomalously high tritium activity at this well whose value remained the same from ~9,200 pCi/L in February 2000 to 9170 pCi/L in December 2000 (Hartman et al 2002). Tritium values at other nearby wells ranged from 3,530 to 5,000 pCi/L.

Figure 3-7. Trend Plots of Specific Conductance for WMA A-AX.

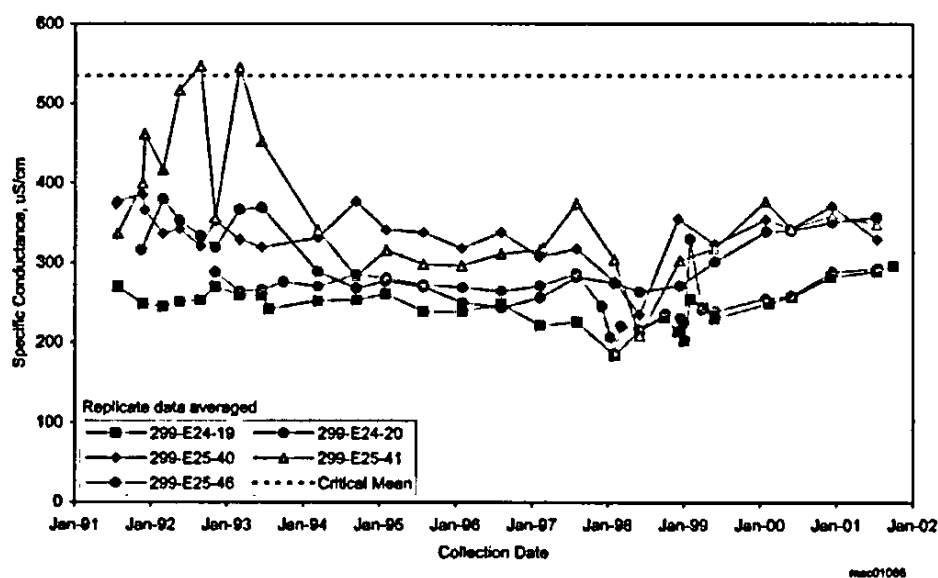


Figure 3-8 Trend Plots of Sulfate for WMA A-AX.

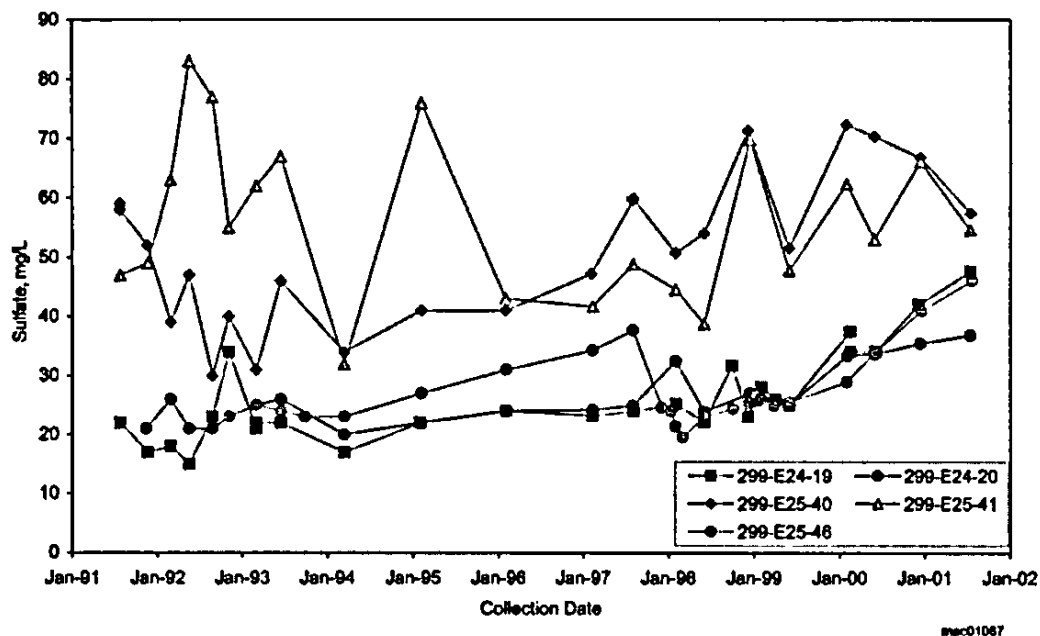
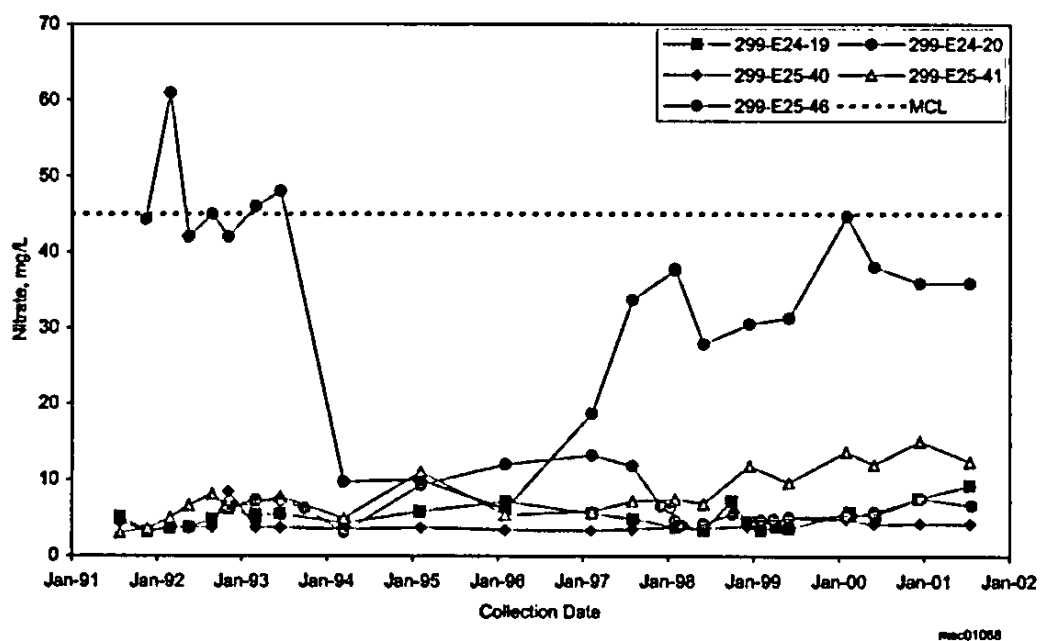


Figure 3-9. Trend Plots of Nitrate for WMA A-AX.

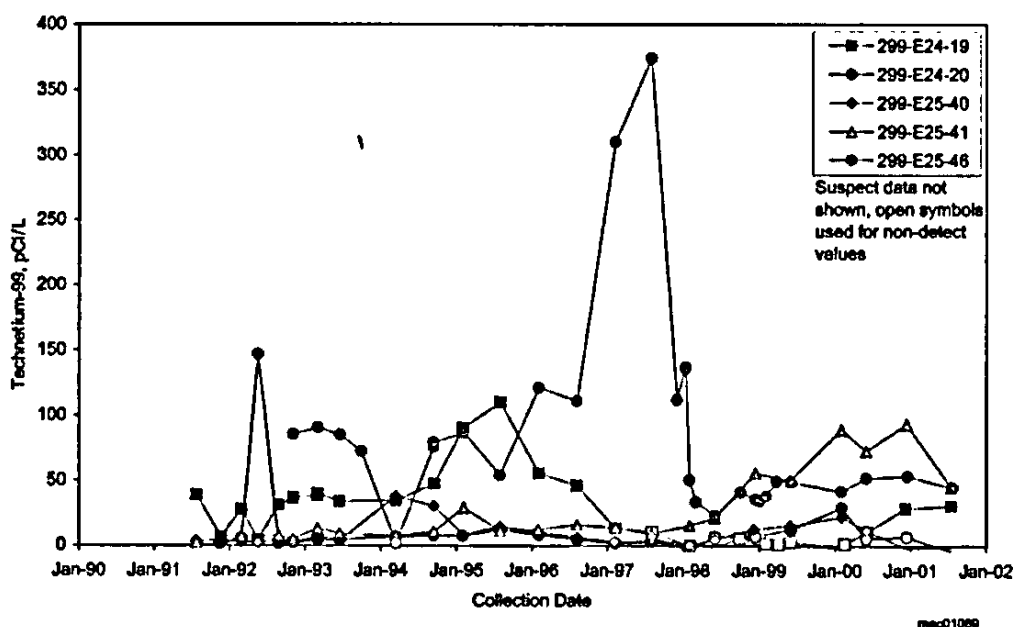




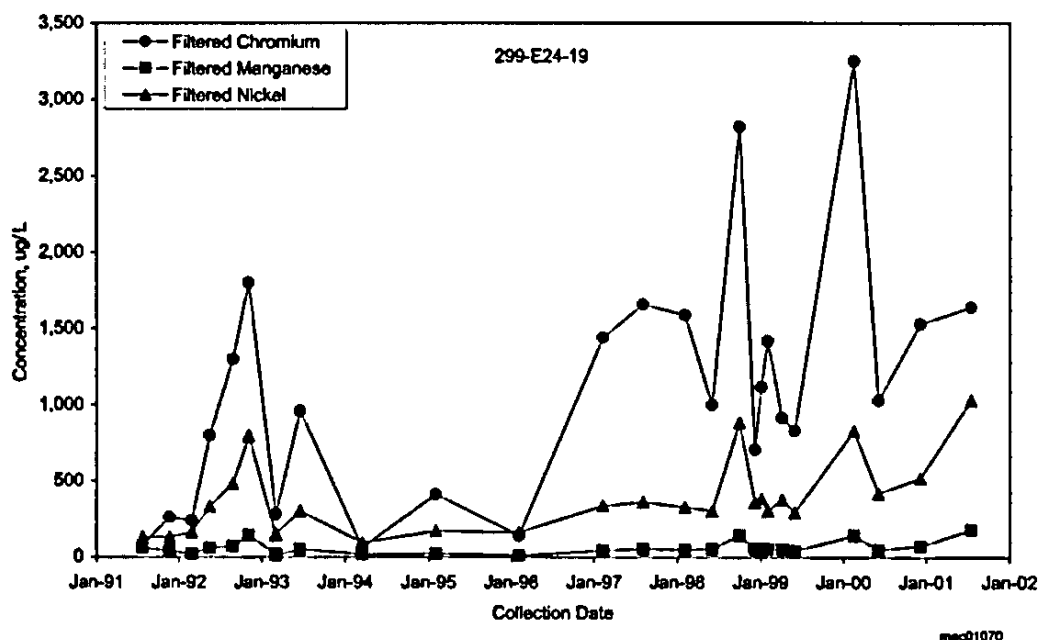
Technetium-99 concentrations for the same set of wells at this WMA are generally low (Figure 3-10), the one notable exception being in well 299-25-46 where a moderate increase in activity to about 400 pCi/L was measured in 1997. Comparison of nitrate and technetium-99 trends in these wells (figures 3-9 and 3-10) show no particular correlation, an observation that frequently is attributed to a vadose zone tank waste source..

In filtered samples from well 299-E24-19, chromium continues to be detected at values above the DWS of 100 ug/L. The last reported value in July 2001 is 1640 ug/L (Figure 3-11). The similarity of manganese and nickel concentration trends to chromium (Figure 3-11) indicate well screen corrosion effects rather than a tank waste source. To test this hypothesis, changes in well 299-E34-19 water chemistry were measured over a 40 minute period at a pumping rate of 3 gallons per minute in December 2000. During that time chromium concentrations dropped noticeably while specific conductance remained relatively constant (Figure 3-12). This suggests that chromium is only present near the borehole relative to those constituents prevalent in the groundwater and contributing to specific conductance measurements (e.g., nitrate, sulfate, sodium). Because chromium is a product of well casing corrosion, the supply is rapidly used up and concentrations fall quickly.

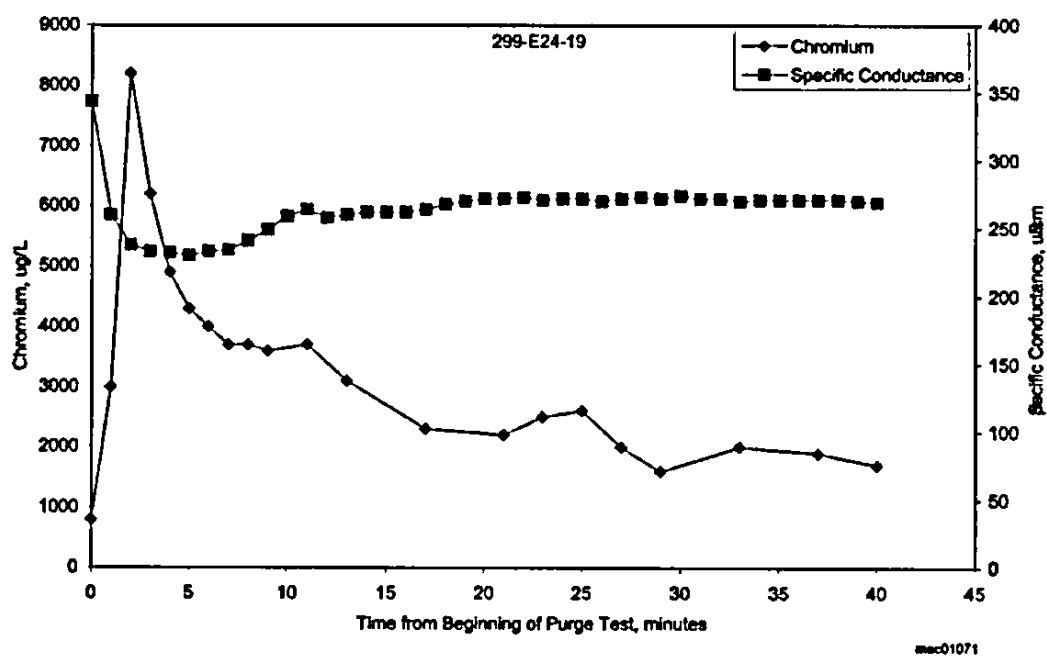
Figure 3-10. Trend Plots of Technetium-99 for WMA A-AX.



**Figure 3-11 Trend Plots for Filtered Chromium, Nickel, and Manganese, for Well 299-E24-19. These data are from filtered samples.**



**Figure 3-12. Trend Plots for Filtered Chromium and Specific Conductance for Well 299-E24-19. These data are from filtered samples.**



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## **4.0 DATA INTEGRATION AND CONTAMINANT MIGRATION CONCEPTUALIZATION**

This section provides qualitative hypotheses and conclusions about the nature and distribution of contamination present in the C and A-AX WMAs. The bases for these observations are the data described in Chapter 3 and the appendices.

### **4.1 GENERAL OBSERVATIONS**

Multiple vadose zone contamination events have occurred in the C and A-AX WMAs. Evidence for these events is provided by the historical record, and historical gross gamma and spectral gamma data. Outstanding characteristics of contaminant occurrences in these WMAs include the following:

- The primary gamma emitting radionuclides measured in the C, A, and AX Tank Farms are Cs-137, Co-60, and Eu-154. Antimony (Sb)-125 is occasionally measured and historical gross gamma evaluations indicate the presence of Ru-106 in the 1970s, which has since decayed to negligible quantities.
- Cesium-137 contamination is found from the surface down to as much 30 ft (9 m) bgs in the majority of drywells in the C, A and AX Tank Farms. Typically, Cs-137 concentrations are < 10 pCi/g and are at maximum value just below the surface. This contamination is attributed to surface spills from tank farm activity. The most contaminated area apparently caused by a surface spill occurs in the AX Tank Farm between and on the north side of tanks AX-103 and AX-101. The drywell with the highest contamination, 11-01-10, contains up to 4,000 pCi/g between 3 and 5 ft (1 and 3 m) bgs. Co-60 and Eu-154 are also present in this borehole.
- Cesium-137 is most highly concentrated in drywell 30-05-07 next to the southwest part of tank C-105 where two zones at and just below the tank bottom (between 34 and 44 ft (10 and 13 m) bgs and 48 and 62 ft (15 and 19 m)) contain maximum concentrations of  $10^7$  and  $10^5$  pCi/g, respectively.
- Co-60 is concentrated in a few areas within these WMAs, including the eastern half of the C Tank Farm, between tanks A-101 and A-102 at the south end in the A Tank Farm, and in the northwestern quadrant of AX Tank Farm. Co-60 occurs most frequently and at greater depth (> 90 ft (27 m) bgs) in the eastern part of the C Tank Farm. Historical gross gamma data indicate Co-60 migration in the late 1970s and early 1980s in the C Tank Farm drywells near presumed transfer line leaks between tanks C-104 and C-105, between tanks C-108 and C-109 and around tank C-103. Co-60 is also tracked in drywells between tanks A-102 and A-102 at the south end between in the late 1970s and 1980s. The deepening progression of Co-60 over time is clearly illustrated at drywell 10-01-04.

- Gross gamma measurements in the 1960s in laterals underneath tanks A-104 and A-105 are the primary indicators of tank waste constituents leaked in the vadose zone from structural failure of these tanks.
- Unintentional releases of tank waste occurred sporadically during tank farm operations. From a vadose zone contamination perspective, the most significant losses occurred from two transfer lines at the west and southwest edge of the C WMA (UPR-200-E-82 and UPR-200-E-86). In both cases, high activity PUREX waste leaked into the vadose zone.
- Unintentional releases of raw water in the tank farms do not appear to have been common. One reported incident occurred on the east side of the A Tank Farm in 1978. A two-inch water line broke and released an estimated 60,000 gal (227,000 L) created a cave in at the surface between the tanks A-102 and A-105 (Caggiano 1991).

These observations clearly show that multiple contamination events have occurred and varying degrees of contamination in the vadose zone have resulted. Integration of the data and conceptualization of leak events associated with the larger contamination areas in the C and A-AX WMAs are described in greater detail in Section 4.2.

## **4.2 CONCEPTUALIZATION OF PRIMARY VADOSE ZONE CONTAMINATION EVENTS**

Three types of vadose zone contamination events occurred in the C and A-AX WMAs. These include surface spills attributed to various unspecified tank farm activities, waste transfer line leaks, and tank leaks. Conceptual models are provided in the following sections for those leaks that have discharged the largest inventories into the vadose zone. Several assumed leaks are not discussed further because neither the historical record nor the field evidence supports a substantive tank waste loss to the vadose zone. These include assumed tank leaks from tanks C-110, C-111, A-103, AX-102 and AX-104. At tank C-101, two potential tank bottom leaks can be inferred from Cs-137 peaks at about 37 ft (11 m) bgs. One is on the west (drywell 20-01-09) and the other is on the south (drywell 30-01-06) side of tank C-101. In both cases, peak concentrations are less than 1000 pCi/g. The isolated contamination at this depth and the small peak concentrations could indicate a very small leak. Another possibility is the accumulation of activity at the compacted base of the tank farm excavation.

Several small transfer line discharges are indicated by peak concentrations of gamma emitting radionuclides in a single drywell that occur between 5 and 40 ft (2 and 12 m) bgs. Usually, the indicator radionuclide is Cs-137 and the high concentration depth interval is small, about 2 ft (1 m) thick. These factors lead to the conclusion that the areal extent of the discharge is small and the contaminant concentrations in the discharged fluid are low. Apparent transfer line leaks with these characteristics in the C and A-AX WMAs include the following:

- An apparent discharge on the north (drywell 30-07-11) side of tank C-107 indicated by an above detection concentration zone between 1 and 5 ft (1 and 2 m) bgs which is interpreted as contaminants contained in a nearby saltwell transfer line rather than a leak (DOE-GJO 1997b)

- A discharge on the north (drywell 30-12-13) of tank C-112 indicated by peaks of non identified radionuclides exceeding the detection limit at about 10 ft (3 m) bgs
- A discharge between tanks A-102 and A-103 (drywell 10-03-10) indicated by Cs-137, Co-60 and Eu-154 peaks (maximum values of 10, 0.5 and 8 pCi/g, respectively) between 5 and 10 (2 and 3 m) bgs

The remaining contamination areas that are considered to be the largest inventory contributors to the vadose zone in the C and A-AX WMAs are tank leaks from tanks C-105, A-105, A-104 and unplanned releases from transfer lines at the west and southwest edge of the C WMA. Smaller discharges also occurred from transfer lines between tanks C-104 and C-105, between tanks C-108 and C-109, between and south of tanks A-101 and 102, between and north of tanks AX-101 and AX-103, and between and west of tanks AX-103 and A-104.

#### 4.2.1 Tank C-105 Data Integration and Interpretation

Tank C-105 has not been identified as a leaker in the past although it has been proposed as possible previously (Brodeur 1993). Two observations suggest that C-105 did leak. First, the spectral gamma data in drywell 30-05-07 on the southwest side of the tank contain two high Cs-137 zones near and just below the tank bottom, which indicates a past occurrence of a tank leak at the tank bottom. Second, a liquid level drop of 36 inches was noted between 1963 and 1967. During this time and into the early 1970s, C-105 was being used as a transfer tank for high activity PUREX waste being sent to B Plant for Cs-137 separation. This waste created high heat conditions in tank C-105 for several years. It is proposed that the high heat load in tank C-105 caused tank failure from rupture of the tank liner at a point of weakness (e.g., the weld between the sidewall and the bottom). Subsequently, a small loss of tank waste into the vadose zone occurred. This combination of tank history and environmental characteristics are similar to other tanks that are known to have leaked (e.g., tank T-106).

Alternative explanations for the causes of these observations other than a tank leak have been proposed. The Cs-137 source has been attributed to a nearby leaking transfer line between tanks C-104 and C-105, about 20 ft (6 m) from the tank bottom. This explanation seems unlikely because a temporary in situ chemical condition that enhanced Cs-137 mobility was needed to allow transport of Cs-137 at high concentrations a distance of more than 20 ft away from the source. Previous single-shell tank leak characterization studies indicate that enhanced mobility has only occurred during the tank SX-108 leak when extremely high sodium concentrations in the waste successfully competed with Cs-137 for sorption sites, allowing Cs-137 to be nonreactive with soils temporarily and migrate more than a few feet from the source location (Knepp 2002). The PUREX waste stream presumed lost from tank C-105 does not appear to have the correct chemistry to enhance Cs-137 mobility even temporarily (e.g., highly concentrated sodium or other competing cations). The observed liquid level drop is less convincing. The high waste heat load could certainly have induced evaporation and at least part of the liquid level drop. Nevertheless, some liquid loss due to tank failure is plausible.

The Cs-137 contamination was encountered when drywell 30-05-07 was drilled in the early 1970s. Therefore, the postulated leak would have occurred previously, probably in the late

1960s. It is hypothesized that the leak was small and self-sealed after a short time. Tank C-105 continued as a feeder tank to B Plant into the 1970s showing no obvious indication of leaking. An analysis of historical gross gamma logging data from this dry well indicates there have been no changes in the level or location of the Cs-137 contamination in the vadose zone since the drywell was installed. In addition, additional liquid level drops after 1967 were not observed. The waste volume released from tank C-105 is unknown and it is feasible that some areas underneath tank C-105 may be highly contaminated. Two distinctly separate high Cs-137 contamination zones with markedly different concentration levels (about  $10^7$  pCi/g in the upper zone at tank bottom depth versus  $10^5$  pCi/g in the lower zone) may indicate two leak events. Another option is that the lower zone indicates a dragdown effect because the contamination was in place at the time of drilling. The 36-inch liquid level drop in a 75 ft diameter tank corresponds to about 100,000 gallons, but evaporation because of high internal tank temperatures was likely responsible for most if not all of the liquid loss. The high Cs-137 vadose zone contamination area at tank T-106 (Wood et al 2001) can be used as a qualitative measuring stick for the size of the tank C-105 leak. At tank T-106, 115,000 gal of tank waste leaked into the vadose zone. During the T-106 leak approximately 40,000 Ci of Cs-137 was lost resulting in a high Cs-137 ( $\sim 10^7$  pCi/g) plume extending over a 75 ft-diameter area. The area of the C-105 high Cs-137 concentration zone is much smaller as it is expressed by only one borehole. Given the uncertainty about contamination underneath the tank, a leak involving the loss of approximately 10,000 Ci of Cs-137 is feasible. The Cs-137 activity in the PUREX supernatant in tank C-105 at the time of the potential leak was in the range of 5 to 30 Ci/gal Cs-137. Thus, a leak volume could be as small as several hundred gallons up to 2 kgal. A leak inventory estimate was developed for a nominal 1-kgal leak volume.

Since the timing of the waste loss event resulting in the Cs-137 activity in drywell 30-05-07 can only be constrained by the time of the drywell installation (early 1970s), waste stream identification, and thus leak inventory, are somewhat problematic. Tank C-105 was first used to store bismuth phosphate metal waste. From 1954 through it was used to store uranium recovery waste. The spectral gamma logging data from drywell 30-05-07 are inconsistent with a leak from either of these two waste types. From 1956 until 1963 tank C-105 was used to store PUREX cladding waste. The concentrations of radionuclides in cladding waste were 3 to 4 orders of magnitude less than in the high-level waste supernatants passing through this tank from 1963 until 1978. Thus, if a PUREX cladding waste were the source of the Cs-137 found in drywell 30-05-07 then a much larger leak volume would be required. However, the leak inventory would remain relatively constant.

Contaminant migration from drywell 30-05-07 to surrounding drywells is not clearly indicated by the spectral gamma data in these surrounding drywells. Two other nearby drywells, 30-5-08 and 30-05-05, show Cs-137 peaks at depths corresponding to the high concentration zones at drywell 30-05-07. In these drywells, maximum Cs-137 concentrations are  $< 100$  pCi/g, much reduced relative to those at drywell 30-05-07. If this Cs-137 is from a tank C-105 leak, the rapid reduction in Cs-137 concentrations is consistent with the expected high Cs-137 reactivity with vadose zone soils. At drywell 30-05-05, Co-60 also appears to peak just below Cs-137 (at 70 ft (21 m) bgs versus 60 to 65 ft (18 to 20 m) bgs). If Cs-137 and Co-60 at this drywell location are both from the tank C-105 leak, Co-60 is nearly as reactive as Cs-137.

From this minimal data set, it is concluded that the proposed tank C-105 leak is largely constrained to the area southwest of tank C-105. However, a more mobile constituent such as Tc-99 probably migrated over a larger area that cannot be predicted with the available data.

#### **4.2.2 Tank A-105 and A-104 Data Integration and Interpretation**

Tanks A-105 and A-104 have been identified as leakers, a conclusion that is clearly supported by the available database. Of these, the tank A-105 leak event was the most serious (see Caggiano 1991, WHC 1991, and Beard et al 1967 for extensive reviews). Both tanks were used to store highly radioactive PUREX processing waste, and were designed to accommodate the high fission product waste and associated high thermal load. In 1963, the first indication of a leak at tank A-105 occurred with the measurement of elevated gamma activity in lateral 14-05-03 on the east side of the tank. This leak was thought to have self-sealed. The tank was then filled to capacity with PUREX high-level (boiling) waste in late 1964. However, the thermal conditions turned out to be too extreme. In January 1965, a steam eruption occurred at tank A-105. Steam was vented for 30 minutes and there was extensive damage to in-tank monitoring equipment. In addition, there was serious damage to the steel base of the tank. There were major safety concerns about the status of this tank at that time. Initial investigations identified a maximum 4-inch drop in the waste level in the tank. The tank was closely monitored for the next few years with no evidence of additional leakage even though the steel liner was severely damaged. After the heat load in the wastes in tank A-105 had decreased for 3 or 4 years the supernatant was transferred to B Plant for Cs-137 recovery. Most of the sludge was removed by sluicing. However, a hard heel was left in the tank when increasing activity was noted in nearby drywells. Because of the heat load of the remaining hard heel, water was periodically added to the tank for almost a decade. The volumes associated with the various leak events from tank A-105 are highly uncertain.

The current leak volume estimate for loss of PUREX high-level waste supernatant from tank A-105 vary from 10 to 45 kgal and estimates of losses of cooling water are between 0 and 232 kgal (Hanlon 2002). The volume of high-level waste supernatant lost controls leak inventory estimates. Impacts of cooling waste losses on leak inventory estimates are insignificant.

All of the available data suggest that the volume of high-level waste supernatant lost from tank A-105 is considerably less than the 10-kgal minimum listed in Hanlon (2002). Analytical data for the supernatant in tank A-105 at the time of the steam release event show the Cs-137 concentration was 8.1 Ci/L or 31 Ci/gal. Thus, the 10 kgal leak volume requires that 310,000 Ci of Cs-137 were lost to the soil column. Yet the drywells around tank A-105 have only very low levels of Cs-137 contamination (< 100 pCi/g). Since the PUREX high-level wastes contained the same array of gamma emitting radionuclides as those lost from tank T-106 in 1973, plumes similar to those found near tank T-106 would have been expected around tank A-105. The lack of significant activity in any of the drywells around tank A-105 (DOE-GJO 1999) provides a strong argument for minimum loss of gamma activity during the 1965 steam release event.

A 300,000 Ci Cs-137 loss would imply a loss of about ~90 Ci of Tc-99. The tank leak data in the monthly tank summary report (Hanlon 2002) implies that there was an additional loss of



about 230,000 gal of contaminated water from this tank – likely more than enough water to drive mobile constituents such as Tc-99 to the water table. Yet, the groundwater monitoring program has not detected groundwater contamination that can be associated with the A Tank Farm. Thus, a 10 kgal leak volume for tank A-105 is highly unrealistic. Thus, it is probable the volume of PUREX high-level supernatant lost from tank A-105 is less than 1 kgal. Table 4-1 reports an inventory for a nominal 1-kgal loss from tank A-105.

The tank A-104 leak occurred similarly to the tank A-105 leak. Enhanced gamma activity was noted in lateral 14-04-02 in April 1975 followed by gamma hits at other locations under the tank. As with tank A-105 conditions, little or no contamination from the A-104 leak is found in the surrounding monitoring boreholes. In 1975, the waste stream in tank A-104 was PUREX sludge supernate (produced from PUREX sludge washing prior to acid dissolution for Sr-90 recovery). The Cs-137 activity in the PUREX sludge supernatant was about an order of magnitude lower than in the PUREX supernatants (Larson 1967). The estimated leak volume is very small (500 to 2,500 gallons according to Hanlon [1999]) and cannot be corroborated. Unlike the tank A-105 leak there was little opportunity for subsequent contaminant migration because water was not added to the tank after the leak.

The extent of subsequent migration of mobile constituents in waste leaked from tanks A-105 and A-104 in the vadose zone is not known. It is postulated that vertical migration has been limited by the fact that waste apparently was disposed directly underneath the tanks within the moisture shadow created by the tanks themselves. Without significant infiltration, migration beyond a few feet is unlikely.

Table 4-1. Tank Leak Inventory Estimates for A, AX, and C Tank Farms.  
(3 sheets)

Tank	A-104	A-105	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Vol.	2.0 kgal	1 kgal	1 kgal	36 Kgal	2,600 gal	17,400 gal
Analyte	kg	kg	kg	kg	kg	kg
Na	2.44E+02	4.10E+02	4.49E+02	5.10E+03	1.17E+03	2.14E+03
Al	4.60E+00	7.14E-01	1.52E+01	2.32E+03	3.96E+01	3.93E+01
Fe	8.44E-01	1.80E+00	2.69E+00	1.53E+01	6.99E+00	7.41E+00
Cr	6.69E+00	6.71E+00	9.82E+00	2.18E+01	2.55E+01	5.88E+01
Bi	1.88E-02	4.42E-03	9.66E-02	0.00E+00	2.51E-01	1.60E-01
La	1.41E-09	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Hg	5.58E-04	9.06E-05	1.85E-03	2.75E-01	4.82E-03	4.84E-03
Zr	4.43E-05	1.06E-04	7.57E-04	0.00E+00	1.97E-03	4.27E-04
Pb	9.38E-02	1.34E-02	2.94E-01	4.54E+01	7.65E-01	8.14E-01
Ni	7.96E-01	1.70E+00	2.53E+00	1.23E+01	6.59E+00	6.99E+00
Sr	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Mn	1.10E+00	3.40E-02	2.72E-01	0.00E+00	7.06E-01	9.67E+00
Ca	2.72E+00	5.80E+00	8.70E+00	4.93E+01	2.26E+01	2.38E+01
K	2.26E+00	2.99E+00	2.97E+00	1.34E+01	7.72E+00	1.98E+01
NO3	1.38E+02	1.51E+02	3.15E+02	5.79E+03	8.18E+02	1.21E+03

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Table 4-1. Tank Leak Inventory Estimates for A, AX, and C Tank Farms.  
(3 sheets)

Tank	A-104	A-105	C-105	UPR-200-E-81	UPR-200-E-82	UPR-200-E-86
Leak Vol.	2.0 kgal	1 kgal	1 kgal	36 Kgal	2,600 gal	17,400 gal
Analyte	kg	kg	kg	kg	kg	kg
NO2	1.65E+02	3.49E+02	2.69E+02	1.82E+03	6.98E+02	1.45E+03
CO3	6.62E+01	2.23E+01	6.46E+01	7.40E+01	1.68E+02	5.79E+02
PO4	1.67E+01	1.30E+01	1.64E+00	0.00E+00	4.25E+00	1.48E+02
SO4	5.90E+01	1.82E+02	8.64E+01	1.66E+02	2.25E+02	5.19E+02
Si	7.20E+00	1.43E+01	1.84E+01	0.00E+00	4.79E+01	1.71E+02
F	5.79E-02	1.76E-02	4.41E-01	0.00E+00	1.15E+00	4.89E-01
Cl	5.10E+00	1.23E+01	1.14E+01	5.59E+01	2.95E+01	4.46E+01
DBP	9.27E-02	1.29E+01	4.33E+01	0.00E+00	1.12E+02	0.00E+00
Butanol	3.27E-02	4.54E+00	1.52E+01	0.00E+00	3.96E+01	0.00E+00
TBP	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NPH	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
U-Total	4.26E+00	5.62E+00	7.06E+00	1.30E+02	1.83E+01	3.73E+01
Analyte	Ci	Ci	Ci	Ci	Ci	Ci
H-3	4.68E-02	1.83E+00	6.62E-01	9.95E-02	1.72E+00	3.89E-01
C-14	1.01E-01	3.77E-01	2.76E-01	1.40E-02	7.17E-01	8.86E-01
Ni-59	1.09E-02	4.67E-02	3.50E-02	3.93E-03	9.11E-02	9.59E-02
Ni-63	1.07E+00	4.66E+00	3.39E+00	3.96E-01	8.81E+00	9.39E+00
Co-60	1.02E-01	4.76E-01	1.95E-01	2.03E-02	5.08E-01	8.99E-01
Se-79	1.51E-02	3.00E-02	3.84E-02	3.10E-03	9.99E-02	1.32E-01
Sr-90	2.55E+02	5.10E+02	6.55E+02	3.29E+02	1.70E+03	2.25E+03
Y-90	2.56E+02	5.10E+02	6.53E+02	3.29E+02	1.70E+03	2.25E+03
Zr-93	7.54E-02	1.50E-01	1.91E-01	1.45E-02	4.97E-01	6.61E-01
Nb-93m	5.26E-02	1.05E-01	1.34E-01	1.06E-02	3.48E-01	4.63E-01
Tc-99	7.08E-01	2.67E+00	1.93E+00	1.02E-01	5.01E+00	6.22E+00
Ru-106	3.75E-05	5.45E-05	6.76E-06	3.36E-05	1.76E-05	3.31E-04
Cd-113m	4.52E-01	8.74E-01	1.05E+00	7.07E-02	2.74E+00	3.97E+00
Sb-125	3.84E-01	2.05E+00	4.94E-01	1.11E-01	1.28E+00	3.37E+00
Sn-126	2.26E-02	4.48E-02	5.76E-02	4.74E-03	1.50E-01	1.98E-01
I-129	1.37E-03	5.14E-03	3.73E-03	1.97E-04	9.69E-03	1.20E-02
Cs-134	1.74E-02	1.06E-01	1.54E-02	7.34E-03	3.99E-02	1.53E-01
Cs-137	2.37E+03	9.60E+03	6.33E+03	3.79E+02	1.65E+04	2.08E+04
Ba-137m	2.24E+03	9.12E+03	5.97E+03	3.58E+02	1.55E+04	1.96E+04
Sm-151	5.26E+01	1.05E+02	1.34E+02	1.12E+01	3.48E+02	4.63E+02
Eu-152	1.70E-02	5.84E-02	3.03E-02	2.56E-03	7.89E-02	1.49E-01
Eu-154	2.19E+00	6.26E+00	4.29E+00	4.01E-01	1.12E+01	1.92E+01
Eu-155	1.11E+00	4.21E+00	1.71E+00	1.84E-01	4.46E+00	9.79E+00